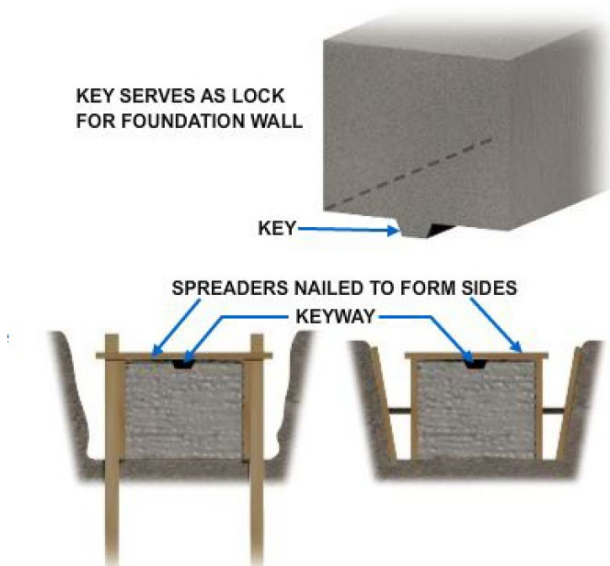
Concrete Construction



12

Professional Development Hours (PDH) or

Continuing Education Hours (CE)

Online PDH or CE course

Concrete Construction

Topics

1.0.0 Concrete Characteristics

2.0.0 Concrete Ingredients

3.0.0 Concrete Mix Design

4.0.0 Mixing Concrete

5.0.0 Formwork

6.0.0 Reinforced Concrete

7.0.0 Concrete Construction Joints

8.0.0 Sawing Concrete

9.0.0 Placing Concrete

10.0.0 Consolidating Concrete

11.0.0 Finishing Concrete

12.0.0 Precast and Tilt-Up Concrete

Overview

More concrete is used than any other man-made material in the world. As of 2006, about seven billion cubic meters of concrete are made each year – more than one cubic meter for every person on Earth.

Concrete is one of the most important construction materials. It is comparatively economical, easy to make, offers continuity and solidity, and will bond with other materials. The keys to good quality concrete are the raw materials required to make it and the mix design specified in the project specifications. The final strength and appearance of concrete depends on the quality control and placement of the concrete. Proper placement methods must be used to prevent ***segregation*** of the concrete.

This chapter covers the characteristics of concrete, its ingredients, its mix designs, and how to mix it, as well as the forming, placement, ***finishing***, and ***curing*** of concrete. It also covers the placement of reinforcing steel and the types of ***ties*** required to ensure that the reinforcing doesn't move once positioned. Concrete ***construction joints*** and the concrete saw are also covered.

We'll conclude the chapter with a discussion of precast and ***tilt-up concrete***. At the end of the discussion, we provide helpful references. You are encouraged to study these references, as required, for additional information on the topics discussed.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Define characteristics of concrete.
2. Identify ingredients essential for good concrete.
3. Calculate concrete mix designs.
4. Determine methods and mixing times of concrete.
5. Describe the types of concrete forms and their construction.
6. Determine the types of ties for and placement of reinforcing steel.
7. Determine the location of construction joints.
8. Determine proper occasions for using the concrete saw.
9. Describe the proper procedures for placing concrete.
10. Describe the methods available for consolidating concrete.
11. Describe the finishing process for the final concrete surface.
12. Determine projects suitable for and lifting methods necessary for precast and tilt-up construction.

Prerequisites

None

This course map shows all of the chapters in Builder Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Expeditionary Structures	↑	B U
Finishes		I
Moisture Protection		L
Carpentry		D
Masonry		E
Fiber Line, Wire Rope, and Scaffolding		R
Concrete Construction		
Site Work		B
Construction Management		A
Drawings and Specifications		S
Tools		I
Basic Math		C

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the

area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 CONCRETE CHARACTERISTICS

Concrete is a synthetic construction material made by mixing ***cement***, fine ***aggregate*** (usually sand), coarse aggregate (usually gravel or crushed stone), and water in the proper proportions. The product is not concrete unless all four of these ingredients are present.

1.1.0 Constituents of Concrete

The fine and coarse aggregates in a concrete mix are the inert, or inactive, ingredients. Cement and water are the active ingredients. The inert ingredients and the cement are first thoroughly mixed together. As soon as the water is added, a chemical reaction begins between the water and the cement. The reaction, called hydration, causes the concrete to harden. This is an important point.

The hardening process occurs through hydration of the cement by the water, not by water drying out of the mix. Instead of being dried out, concrete must be kept as moist as possible during the initial hydration process. Drying out causes a drop in water content below that required for satisfactory hydration of the cement. The fact that the hardening process does not result from drying out is clearly shown by the fact that concrete hardens just as well underwater as it does in air. The proportions of the constituents in concrete are illustrated in *Figure 6-1*.

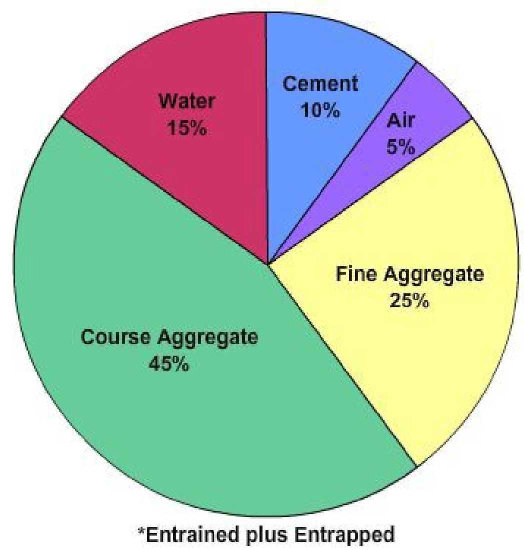


Figure 1 – Proportions of constituents of Concrete.

1.2.0 Concrete as Building Material

Concrete may be cast into bricks, blocks, and other relatively small building units which are used in concrete construction. Concrete has a great variety of applications because it meets structural demands and lends itself to architectural treatment. All important building elements, foundations, columns, walls, slabs, and roofs, are made from concrete. Other concrete applications are in roads, runways, bridges, and dams.

1.3.0 Strength of Concrete

The ***compressive strength*** of concrete, its ability to resist compression, is very high, but its tensile strength, its ability to resist stretching, bending, or twisting, is relatively low. Concrete which must resist a good deal of stretching, bending, or twisting; such as concrete in beams, girders, walls, columns, and the like must be reinforced with steel. Concrete that must resist only compression may not require reinforcement. As you will learn later, one of the most important factors controlling the strength of concrete is the water cement ratio, or the proportion of water to cement in the mix. Another important factor is quality control during the placement of the concrete.

1.4.0 Durability of Concrete

The durability of concrete refers to the extent to which the material is capable of resisting deterioration from exposure to service conditions. Concrete is also strong and fireproof. Ordinary structural concrete to be exposed to the elements must be watertight and weather resistant. Concrete subject to wear, such as floor slabs and pavements, must be capable of resisting abrasion.

The major factor controlling the durability of concrete is its strength. The stronger the concrete, the more durable it is. As we just mentioned, the chief factor controlling the strength of concrete is the water cement ratio. The character, size, and grading i.e., distribution of particle sizes between the largest permissible coarse and the smallest permissible fine, of the aggregate also have important effects on both strength and durability. Maximum strength and durability will still not be attained unless the sand and coarse aggregate you use consist of well graded, clean, hard, and durable particles free of undesirable substances. The relationship of these properties is shown in *Figure 6-2*.

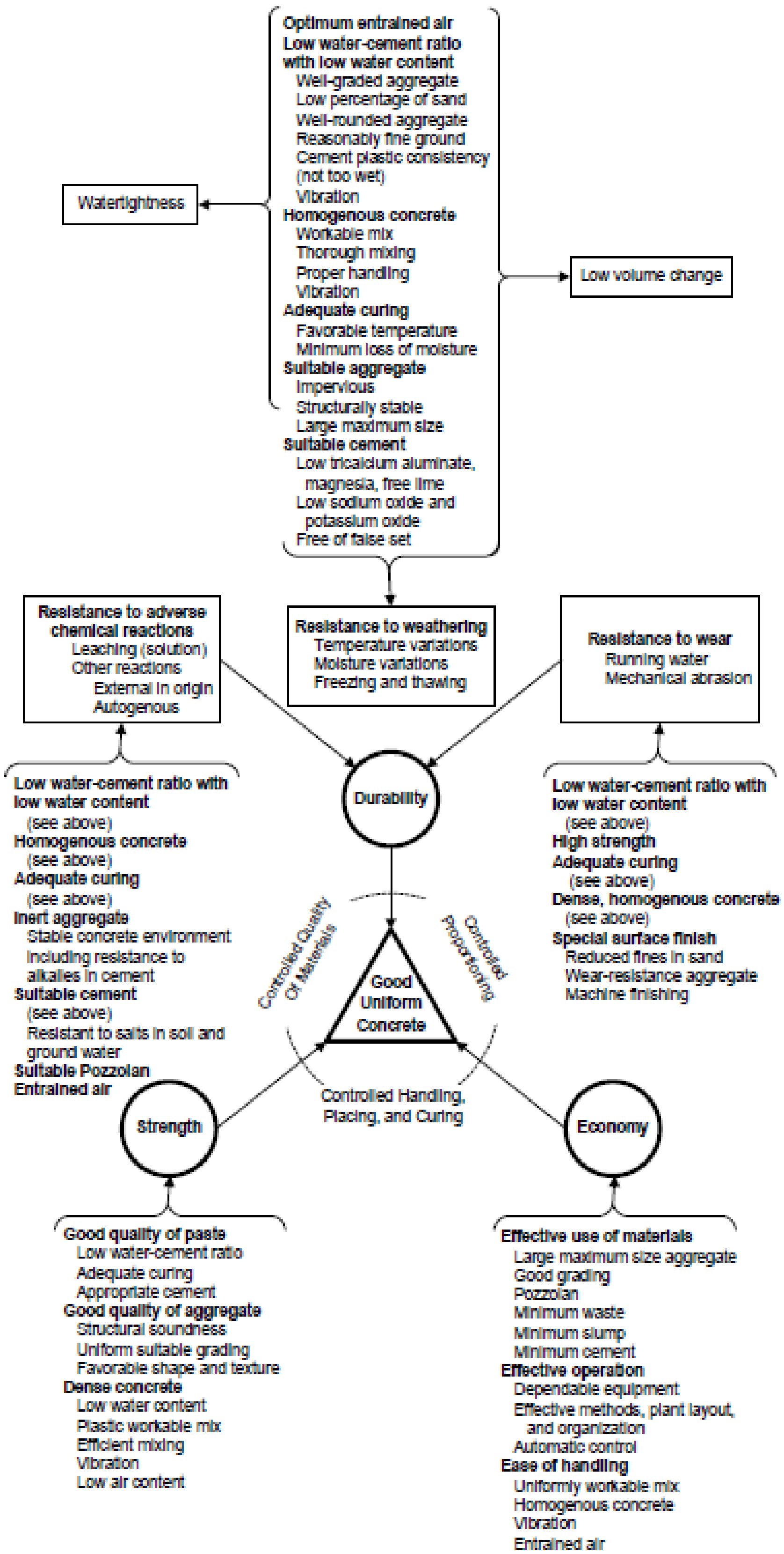


Figure 2 – The principal properties of good concrete.

1.5.0 Watertightness of Concrete

The ideal concrete mix is one with just enough water required for complete hydration of the cement, but this results in a mix too stiff to pour in ***forms***. A mix fluid enough to be poured in forms always contains a certain amount of water over and above that which will combine with the cement. This water eventually evaporates, leaving voids, or pores, in the concrete. Penetration of the concrete by water is still impossible if these voids are not interconnected. They may be interconnected as a result of slight sinking of solid particles in the mix during the hardening period. As these particles sink, they leave water filled channels that become voids when the water evaporates. The larger and more numerous these voids are, the more the watertightness of the concrete is impaired. The size and number of the voids varies directly with the amount of water used in excess of the amount required to hydrate the cement.

To keep the concrete as watertight as possible, you must not use more water than the minimum amount required to attain the necessary degree of ***workability***. You may want to make the concrete mix as wet as possible to reduce the labor of placing the concrete. This is not a good idea because adding water can result in more ***shrinkage*** and lower strength concrete, which may not meet the specifications for the project. You might also end up delaying when finishing work can begin.

The quality of ***troweling*** can impact the watertightness of concrete. Troweling is one of the final stages of finishing concrete, completed after the surface of the concrete has been floated and the bleed water has evaporated. Troweling makes the surface of concrete hard and dense, which contributes to its watertightness.

1.6.0 General Requirements for Good Concrete

The first requirement for good concrete is to use a cement type suitable for the work at hand and have a satisfactory supply of sand, coarse aggregate, and water. Everything else being equal, the mix with the best graded, strongest, best shaped, and cleanest aggregate makes the strongest and most durable concrete.

Second, the amount of cement, sand, coarse aggregate, and water required for each ***batch*** must be carefully weighed or measured according to project specifications.

Third, even the best designed, best graded, and highest quality mix does not make good concrete if it is not workable enough to fill the form spaces thoroughly. On the other hand, too much fluidity also results in defects. Also, improper handling during the overall concrete making process, from the initial aggregate handling to the final placement of the mix, causes segregation of aggregate particles by sizes, resulting in nonuniform, poor quality concrete.

Finally, the best designed, best graded, highest quality, and best placed mix does not produce good concrete if it is not properly cured, that is, properly protected against loss of moisture during the earlier stages of setting.

2.0.0 CONCRETE INGREDIENTS

The essential ingredients of concrete are cement, aggregate, and water. A mixture of only cement and water is called cement paste. In large quantities, cement paste is prohibitively expensive and too weak for most construction purposes.

2.1.0 Portland Cement

Most cement used today is Portland cement. This is a carefully proportioned and specially processed combination of lime, silica, iron oxide, and alumina. It is usually manufactured from limestone mixed with shale, clay, or marl. Properly proportioned raw materials are pulverized and fed into kilns where they are heated to a temperature of 2,700°F and maintained at that temperature for a specific time. The heat produces chemical changes in the mixture and transforms it into clinker, a hard mass of fused clay and limestone. The clinker is then ground to a fineness that will pass through a sieve containing 40,000 openings per square inch.

2.1.1 Types of Cement

There are five types of Portland cement covered under Standard Specifications for Portland Cement. The American Society for Testing and Material (ASTM) types govern these specifications. Separate specifications, such as those required for air-entraining Portland cements, are found under a separate ASTM. The type of construction, chemical composition of the soil, economy, and requirements for use of the finished concrete are factors that influence the selection of the kind of cement to use.

Type I – Type I cement is general purpose cement for concrete that does not require any of the special properties of the other types. In general, type I cement is intended for concrete that is not subjected to sulfate attack or damage by the heat of hydration. Type I Portland cement is used in pavement and sidewalk construction, reinforced concrete buildings and bridges, railways, tanks, reservoirs, sewers, culverts, water pipes, masonry units, and soil-cement mixtures. Generally, it is more available than the other types. Type I cement reaches its design strength in about 28 days.

Type II – Type II cement is modified to resist moderate sulfate attack. It also usually generates less heat of hydration and at a slower rate than type

I. A typical application is for drainage structures where the sulfate concentrations in either the soil or groundwater are higher than normal but not severe. Type II cement is also used in large structures where its moderate heat of hydration produces only a slight temperature rise in the concrete. The temperature rise in type II cement can be a problem when concrete is placed during warm weather. Type II cement reaches its design strength in about 45 days.

Type III – Type III cement is high early strength cement that produces design strengths at an early age, usually 7 days or less. It has a higher heat of hydration and is more finely ground than type I. Type III permits fast form removal and, in cold weather construction, reduces the period of protection against low temperatures. Richer mixtures of type I can obtain high early strength, but type III produces it more satisfactorily and economically. Use it cautiously in concrete structures having a minimum dimension of 2 1/2 feet or more. While there is no set minimum dimension, take caution with massive placements of concrete, as they will produce more heat. The high heat of hydration can cause shrinkage and cracking.

Type IV – Type IV cement is a special cement. It has a low heat of hydration and is intended for applications requiring a minimal rate and amount of heat of hydration. Its strength also develops at a slower rate than the other types. Type IV is used primarily in very large concrete structures, such as gravity dams, where the temperature rise from the heat of hydration might damage the structure. Type IV cement reaches its design strength in about 90 days.

Type V – Type V cement is sulfate resistant and should be used where concrete is subjected to severe sulfate action, such as when the soil or groundwater contacting the concrete has a high sulfate content. Type V cement reaches its design strength in about 60 days.

2.1.2 Air-Entrained Cement

Air-entrained Portland cement is special cement that can be used with good results for a variety of conditions. It has been developed to produce concrete resistant to freeze thaw action and to scaling caused by chemicals applied for severe frost and ice removal. In this cement, very small quantities of air-entraining materials are added as the clinker is ground during manufacturing. Concrete made with this cement contains tiny, well distributed and completely separated air bubbles. The bubbles are so small that there may be millions of them in a cubic foot of concrete.

The air bubbles provide space for freezing water to expand without damaging the concrete. ***Air-entrained concrete*** has been used in pavements in the northern United States for about 25 years with excellent results. Air-entrained concrete also reduces both the amount of water loss and the capillary/water channel structure.

An air-entrained ***admixture*** may also be added to types I, II, and III Portland cement. The manufacturer specifies the percentage of air entrainment that can be expected in the concrete. An advantage of using air-entrained cement is that it can be used and batched like normal cement. The air-entrained admixture comes in a liquid form or mixed in the cement. To obtain the proper mix, add the admixture at the batch plant. More information on admixtures is included later in this chapter.

2.2.0 Aggregates

The material combined with cement and water to make concrete is called aggregate. Aggregate makes up 60 to 80 percent of concrete volume. It increases the strength of concrete, reduces the shrinking tendencies of the cement, and is used as economical filler.

2.2.1 Types

Aggregates are divided into fine, usually consisting of sand, and coarse categories. For most building concrete, coarse aggregate consists of gravel or crushed stone up to 1 1/2 inches in size. In massive structures such as dams, the coarse aggregate may include natural stones or rocks ranging up to 6 inches or more in size.

2.2.2 Purpose of Aggregates

The large, solid coarse aggregate particles form the basic structural members of the concrete. The voids between the larger coarse aggregate particles are filled by smaller particles. The voids between the smaller particles are filled by still smaller particles.

Finally, the voids between the smallest coarse aggregate particles are filled by the largest fine aggregate particles. In turn, the voids between the largest fine aggregate particles are filled by smaller fine aggregate particles, the voids between the smaller fine aggregate particles by still smaller particles, and so on. Finally, the voids between the finest grains are filled with cement. You can see from this that the better the aggregate is graded; that is, the better the distribution of particle sizes, the more solidly all voids will be filled, and the denser and stronger the concrete will be.

The cement and water form a paste that binds the aggregate particles solidly together when it hardens. In a well graded, well designed, and well mixed batch, each aggregate particle is thoroughly coated with the cement-water paste. Each particle is solidly bound to adjacent particles when the cement-water paste hardens.

Aggregate Sieves – The size of an aggregate sieve is designated by the number of meshes to the linear inch in that sieve. The higher the number, the finer the sieve. Any material retained on the No. 4 sieve can be considered either coarse or fine.

Aggregates larger than No. 4 are all coarse; those smaller are all fines. No. 4 aggregates are the dividing point. The finest coarse aggregate sieve is the same No. 4 used as the coarsest fine aggregate sieve. With this exception, a coarse aggregate sieve is designated by the size of one of its openings. The sieves commonly used are 1 1/2 inches, 3/4 inch, 1/2 inch, 3/8 inch, and No. 4. Any material that passes through the No. 200 sieve is too fine to be used in making concrete.

Particle Distribution – Experience and experiments show that for ordinary building concrete, certain particle distributions consistently seem to produce the best results. For fine aggregate, the recommended distribution of particle sizes from No. 4 to No. 100 is shown in *Table 6-1*.

Table 1 – Recommended Distribution of Particle Sizes

Sieve Size	Percent passing, by weight		
	Normal Weight Aggregate	Lightweight Aggregate	Heavy-duty Toppings
3/8”	100	100	95
No. 4	95-100	85-100	95-100
No. 8	80-90	-	65-80
No.16	50-75	40-80	45-65
No. 30	30-50	30-65	35-45
No. 50	10-20	10-35	5-15
No. 100	2-5	5-20	0-5

Determine the distribution of particle sizes in aggregate by extracting a representative sample of the material, screening the sample through a series of sieves ranging in size from coarse to fine, and determining the percentage of the sample retained on each sieve. This procedure is called making a sieve analysis. For example, suppose the total sample weighs 1 pound. Place this on the No. 4 sieve, and shake the sieve until nothing more goes through. If what is left on the sieve weighs 0.05 pound, then 5 percent of the total sample is retained on the No. 4 sieve. Place what passes through on the No. 8 sieve and shake it. Suppose you find that what stays on this sieve weighs 0.1 pound.

Since 0.1 pound is 10 percent of 1 pound, 10 percent of the total sample was retained on the No. 8 sieve. The cumulative retained weight is 0.15 pound. By dividing 0.15 by 1.0 pound, you will find that the total retained weight is 15 percent.

The size of coarse aggregate is usually specified as a range between a minimum and a maximum size; for example, 2 inches to No. 4, 1 inch to No. 4, 2 inches to 1 inch, and so on. The recommended ***particle size distributions*** vary with maximum and minimum nominal size limits, as shown in *Table 6-2*.

Table 2 – Recommended Maximum and Minimum Particle Sizes.

Size of Coarse Aggregate, In Inches	Percentages by Weight Passing Laboratory Sieves Having Square Openings										
	4 in.	3 1/2 in.	3 in.	2 1/2 in.	2 in.	1 1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4
1.5	–	–	–	–	100	95-100	–	35-70	–	10-30	0-5
2	–	–	–	100	95-100	–	35-70	–	10-30	–	0-5
2.5	–	–	100	90-100	–	35-70	–	10-40	–	0-15	0-5
3.5	100	90-100	–	45-80	–	25-50	–	10-30	–	0-15	0-5

A blank space in *Table 6-2* indicates a sieve that is not required in the analysis. For example, for the 2 inch to No. 4 nominal size, there are no values listed under the 4 inch, the 3 1/2 inch, the 3 inch, and the 2 1/2 inch sieves. Since 100 percent of this material should pass through a 2 1/2 inch sieve, there is no need to use a sieve coarser than that size. For the same size designation, 2 inch size aggregate, there are no values listed under the 1 1/2 inch, the 3/4 inch, and the 3/8 inch sieves. Experience has shown that it is not necessary to use these sieves in making this particular analysis.

2.2.3 Quality Standards

Since 66 to 78 percent of the volume of the finished concrete consists of aggregate, the aggregate must meet certain minimum quality standards. It should consist of clean, hard, strong, durable particles free of chemicals that might interfere with hydration. The aggregate should also be free of any superfine material, which might prevent a ***bond*** between the aggregate and the cement-water paste. The undesirable substances most frequently

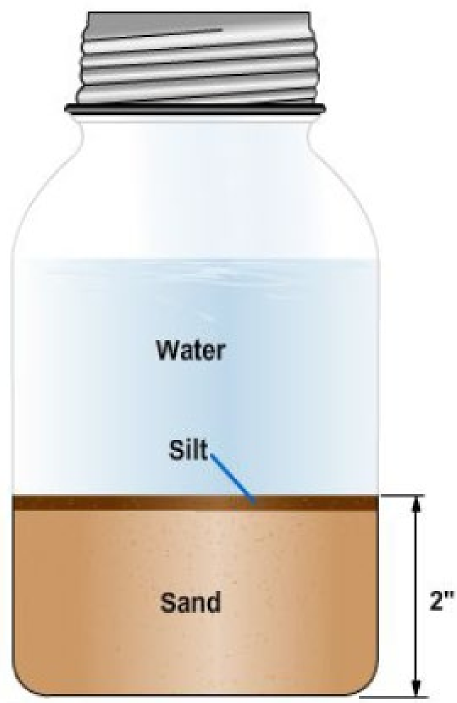


Figure 3 – Quart jar method of determining silt content of sand.

found in aggregate are dirt, silt, clay, coal, mica, salts, and organic matter.

Most of these can be removed by washing. Aggregate can be field tested for an excess of silt, clay, and the like using the following procedure:

1. Fill a quart jar with the aggregate to a depth of 2 inches.
2. Add water until the jar is about three-fourths full.
3. Shake the jar for 1 minute, then allow it to stand for 1 hour.
4. If, at the end of 1 hour, more than 1/8 inch of sediment has settled on top of the aggregate, shown in *Figure 6-3*, the material should be washed.

Figure 6-4 shows an easily constructed rig for washing a small amount of aggregate.

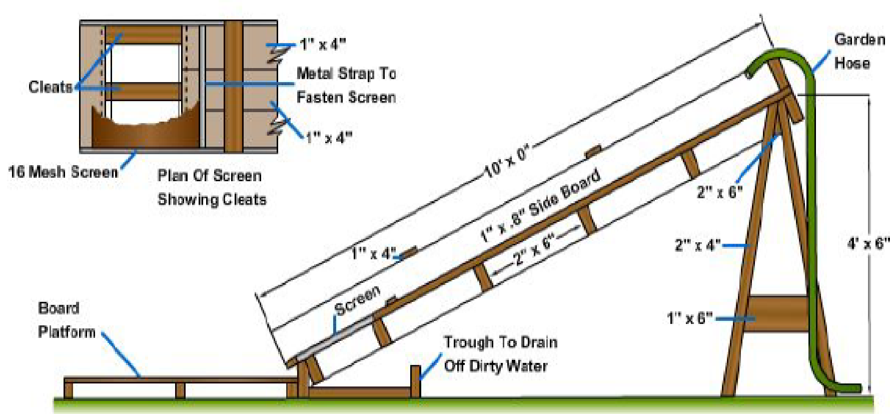


Figure 4 – Field-constructed rig for washing aggregate.

Weak, friable (easily pulverized), or laminated (layered) aggregate particles are undesirable. Especially avoid shale, stones laminated with shale, and most varieties of chert (impure flint-like rock). For most ordinary concrete work, visual inspection is enough to reveal any weaknesses in the coarse aggregate. For work in which aggregate strength and durability are of vital importance, such as paving concrete, aggregate must be laboratory tested.

Table 3 – Harmful Substances in Aggregates (from ASTM C 33).

Item	Fine Aggregate	Coarse Aggregate
Clay lumps and friable particles	Unsound particles may affect durability and workability, cause popouts, increase water demand of mix	
Coal and lignite	Affect surface appearance; cause popouts and difficulty in air entrapment	
Material finer than No. 200 sieve	Affects bond of paste to aggregate and increases the mix water demand	Can cause trouble when it exists as a coating on coarse aggregate
Soft particles	-	Reduce durability and surface hardness
Lightweight chert (specific gravity less than 2.40)	-	Reduces durability; a main cause of popouts

Figure 6-5 shows a popout, which occurs when internal pressure causes a small part of the concrete surface to break away.
This usually leaves a cone-shaped hole, ranging in size from 1/4 inch or less to 2 inches or more. (Photo courtesy of http://www.all-things-concrete.com.)

Figure 5 – Popout.

2.2.4 Handling and Storage

A mass of aggregate containing particles of different sizes has a natural tendency toward segregation. Segregation refers to particles of the same size tending to gather together when the material is loaded, transported, or otherwise disturbed. Always handle and store aggregate by a method that minimizes segregation.

Do not build up stockpiles in cone shapes, formed by dropping successive loads at the same spot. This procedure causes segregation. Build a pile up in layers of uniform thickness, each made by dumping successive loads alongside each other.

If aggregate is dropped from a clamshell, bucket, or conveyor, some of the fine material may be blown aside, causing segregation of fines on the side of the pile away from the wind. Discharge all conveyors, clamshells, and buckets in contact with the pile.

When ***charging*** (filling) a bin, drop the material from a point directly over the outlet. Material chuted in at an angle or material discharged against the side of a bin will segregate. Since a long drop will cause both segregation and the breakage of aggregate particles, minimize the length of a drop into a bin by keeping the bin as full as possible at all times. The bottom of a storage bin should always slope at least 50˚ toward the central outlet. If the slope is less than 50 ˚, segregation will occur as material is discharged out of the bin.

2.3.0 Water

The two principal functions of water in a concrete mix are to effect hydration and improve workability. For example, a mix to be poured in forms must contain more water than is required for complete hydration of the cement. Too much water causes a loss of strength by upsetting the water-cement ratio. It also causes water gain on the surface, a condition that leaves a surface layer of weak material called ***laitance***. As previously mentioned, an excess of water also impairs watertightness of the concrete.

Water used in mixing concrete must be clean and free from acids, alkalis, oils, or organic materials. Most specifications recommend that the water used in mixing concrete be suitable for drinking (potable), if such water is available.

Seawater can be used for mixing unreinforced concrete if there is a limited supply of fresh water. Tests show that the compressive strength of concrete made with seawater is 10 to 30 percent less than that obtained using fresh water. Seawater is not suitable for use in making steel reinforced concrete because of the risk of corrosion of the reinforcement, particularly in warm and humid environments.

2.4.0Admixtures

Admixtures include all materials added to a mix other than Portland cement, water, and aggregates. Admixtures are sometimes used in concrete mixtures to improve certain qualities, such as workability, strength, durability, watertightness, and wear resistance. They may also be added to reduce segregation, reduce the heat of hydration, entrain air, and accelerate or retard setting and hardening.

We should note that the same results can often be obtained by changing the mix proportions or by selecting other suitable materials without resorting to the use of admixtures, except air-entraining admixtures when necessary. Whenever possible, compare these alternatives to determine which is more economical or convenient. Seabees rely on local suppliers for appropriate basic concrete mixes. Add any admixture according to current specifications determined by the Engineering Aid and upon approval of the Quality Control department.

2.4.1 Workability Agents

Materials such as hydrated lime and bentonite improve workability. These materials increase the fines in a concrete mix when an aggregate is tested deficient in fines, i.e., lacking sufficient fine material.

2.4.2 Air-Entraining Agents

The deliberate adding of millions of minute disconnected air bubbles to cement paste, if those bubbles are evenly diffused, changes the basic concrete mix and increases durability, workability, and strength. The acceptable amount of entrained air in a concrete mix, by volume, is 3 to 7 percent. ***Air-entraining agents***, used with types I, II, or III cement, are derivatives of natural wood resins, animal or vegetable fats, oils, alkali salts of sulfated organic compounds, and water soluble soaps. Most air-entraining agents are in liquid form for use in the mixing water.

2.4.3 Accelerating admixtures

Accelerating admixtures speed up the setting and hardening of concrete. They are especially useful in cold weather because concrete hardens slowly at temperatures below about 50□F. In the past, the most common of these admixtures was calcium chloride. However, calcium chloride in concrete increases the potential for corrosion of reinforcing steel and some other metals. When required by the specifications, non- chloride ***accelerators*** are available.

2.4.4 Retarders

The accepted use for ***retarders*** is to reduce the rate of hydration. They are often used in warm weather to keep the concrete from setting before it can be placed and finished. Agents normally used are fatty acids, sugar, and starches.

2.5.0 Cement Storage

Portland cement is packed in cloth or paper sacks, each weighing 94 pounds. A 94 pound sack of cement amounts to about 1 cubic foot by loose volume.

Cement will retain its quality indefinitely if it does not come in contact with moisture. If allowed to absorb appreciable moisture in storage, it sets more slowly and its strength is reduced. Store sacked cement in warehouses or sheds made as watertight and airtight as possible. Close all cracks in roofs and walls, and ensure there are no openings between walls and roof. The floor should be above ground to protect the cement against dampness. Keep all doors and windows closed.

Stack sacks against each other to prevent circulation of air between them, but do not stack them against outside walls. If stacks are to stand undisturbed for long intervals, cover them with tarpaulins.

When shed or warehouse storage is not available, sacks that must be stored in the open should be stacked on raised platforms and covered with waterproof tarps. The tarps should extend beyond the edges of the platform to deflect water away from the platform and the cement.

Cement sacks stacked in storage for long periods sometimes acquire a hardness called warehouse pack. You can usually loosen this by rolling the sack around. Do not use cement that has lumps or is not free flowing.

3.0.0 CONCRETE MIX DESIGN

Before proportioning a concrete mix, you need information concerning the job, such as size and shapes of structural members, required strength of the concrete, and exposure conditions. The end use of the concrete and conditions at time of placement are additional factors to consider.

3.1.0 Ingredient Proportions

The ingredient proportions for the concrete on a particular job are usually set forth in the specifications under CONCRETE - General Requirements. See *Table 6-4* for examples of normal concrete mix design and the number of bags of cement used in the mixing specifications according to NAVFAC.

In *Table 6-4*, one of the formulas for 3,000 psi concrete is 5.80 bags of cement per cubic yard, 233 pounds of sand (per bag of cement), 297 pounds of coarse aggregate (per bag of cement), and a water-cement ratio of 6.75 gallons of water to each bag of cement. These proportions are based on the assumption that the inert ingredients are in a saturated surface dry condition, meaning that they contain all the water they are capable of absorbing, but no additional free water over and above this amount.

Table 4 – Normal Concrete.

Figures Denote Size of Coarse Aggregate in Inches (1)	Estimated 28 Day Compressive Strength (Pounds per Square Inch) (2)	Cement Factor Bags (94 Pounds) of Cement per Cubic Yard of Concrete Freshly Mixed (3)	Maximum Water (Gallons) per Bag (94 Pounds) of Cement (4)	Fine Aggregate Range in Percent of Total Aggregate by Weight (5)	Approximate Weights of Saturated Surface Dry Aggregates per Bag (94 Pounds) of Cement: Fine Aggregate Pounds (6)	Coarse Aggregate Pounds (7)
1	1,5004.10		9.50	42-52	368	415
1-1.5	1,5003.80		9.50	38-48	376	498
2	1,5003.60		9.50	35-45	378	567
2.5	1,5003.50		9.50	33-43	373	609
3.5	1,5003.25		9.50	30-40	378	702
1	2,0004.45		8.75	41-51	329	387
1.5	2,0004.10		8.75	37-47	338	467
2	2,0003..90		8.75	34-44	338	529
2.5	2,0003.80		8.75	32-42	332	565
3.5	2,0003.55		8.75	29-39	334	648
0.5	2,5005.70		7.75	50-60	282	231
0.75	2,5005.30		7.75	45-55	288	288
1	2,5005.05		7.75	40-50	279	341
1.5	2,5004.65		7.75	36-46	287	413
2	2,5004.40		7.75	34-42	288	471
2.5	2,5004.25		7.75	32-40	287	509
3.5	2,5004.00		7.75	29-37	285	578
0.5	3,0006.50		6.75	50-58	238	203
0.75	3,0006.10		6.75	45-53	240	249
1	3,0005.80		6.75	40-48	233	297
1.5	3,0005.35		6.75	36-44	239	359
2	3,0005.05		6.75	33-41	241	410
2.5	3,0004.90		6.75	31-39	238	441
3.5	3,0004.60		6.75	28-36	237	503
0.375	3,5007.70		6.00	56-64	210	140
0.5	3,5007.35		6.00	48-56	198	183
0.75	3,5006.85		6.00	43-51	201	226
1	3,5006.50		6.00	38-46	195	270
1.5	3,5006.00		6.00	34-42	200	325
2	3,5005.70		6.00	31-29	199	369
2.5	3,5005.50		6.00	29-37	197	400
3.5	3,5005.20		6.00	27-35	200	444
0.25	4,0008.95		5.50	100	281	–
0.375	4,0008.40		5.50	55-63	186	129
0.5	4,0008.00		5.50	47-55	175	168
0.75	4,0007.45		5.50	42-50	178	209
1	4,0007.10		5.50	37-45	172	247
1.5	4,0006.55		5.50	33-41	175	299
2	4,0006.20		5.50	30-38	175	340
2.5	4,0006.00		5.50	28-36	173	368
3.5	4,0005.65		5.50	26-34	176	411
0.25	5,00011.50		4.25	100	202	–
0.375	5,00010.80		4.25	53-61	130	98
0.5	5,00010.35		4.25	45-53	121	126
0.75	5,0009.65		4.25	40-48	123	157
1	5,0009.20		4.25	35-43	119	186
1.5	5,0008.45		4.25	31-39	122	228
2	5,0008.00		4.25	28-36	122	260

A saturated surface dry condition almost never exists in the field. The amount of free water in the coarse aggregate is usually small enough to be ignored, but always adjust the ingredient proportions set forth in the specs to allow for the existence of free water in the fine aggregate. Furthermore, since free water in the fine aggregate increases its measured volume or weight over that of the sand itself, the specified volume or weight of sand must be adjusted to offset the volume or weight of the water in the sand. Finally, reduce the number of gallons of water used per sack of cement to allow for the free water in the sand. The amount of water actually added at the mixer must be the specified amount per sack, less the amount of free water that is already in the ingredients in the mixer.

Except as otherwise specified in the project specifications, concrete is proportioned by weighing and must conform to NAVFAC specifications. See *Table 6-4* for normal concrete.

3.2.0Material Estimates

When tables such as *Table 6-4* are not available for determining quantities of material required for 1 cubic yard of concrete, a rule of thumb known as rule 41 or 42 may be used for a rough estimation. According to this rule, it takes either 41 or 42 cubic feet of the combined dry amounts of cement, sand, and aggregates to produce 1 cubic yard of mixed concrete. Rule 41 is used to calculate the quantities of material for concrete when the size of the coarse aggregate is not over 1 inch. Rule 42 is used when the size of the coarse aggregate is over 1 inch but not larger 2 1/2 inches. Here is how it works.

As we mentioned earlier, a bag of cement contains 94 pounds by weight, or about 1 cubic foot by loose volume. A batch formula is usually based on the number of bags of cement used in the mixing machine.

For estimating the amount of dry materials needed to mix 1 cubic yard of concrete, rules 41 and 42 work in the same manner. The decision on which rule to use depends upon the size of the aggregate. Let’s say your specifications call for a 1:2:4 mix with 2-inch coarse aggregates, which means you use rule 42. First, add 1:2:4, which gives you 7.
Then compute your material requirements as follows:

42 ÷ 7 = 1 x 6 = 6 cu ft of cement;

6 x 2 = 2 x 6 = 12 cu ft of sand;

6 x 4 = 4 x 6 = 24 cu ft of coarse aggregates.

Adding your total dry materials, 6 + 12 + 24 = 42, so your calculations are correct.

Frequently, you will have to convert volumes in cubic feet to weights in pounds. In converting, multiply the required cubic feet of cement by 94 since 1 cubic foot, or 1 standard bag of cement, weighs 94 pounds. When using rule 41 for coarse aggregate, multiply the quantity of coarse gravel in cubic feet by 105 since the average weight of dry compacted fine aggregate or gravel is 105 pounds per cubic foot. By rule 42, multiply the cubic feet of rock (1 inch size coarse aggregate) by 100 since the average dry compacted weight of this rock is 100 pounds per cubic foot.

Include a handling loss factor in ordering materials for jobs. Add an additional 5 percent for jobs requiring 200 or more cubic yards of concrete, and 10 percent for smaller jobs. This loss factor is based on material estimates after the requirements have been calculated. You may add additional loss factors where conditions indicate the necessity for excessive handling of materials before batching.

3.2.1 Measuring Water

The water measuring controls on a machine concrete mixer are described later in this chapter. Water measurement for hand mixing can be done with a bucket, marked off on the inside in gallons, half gallons, and quarter gallons.

Never add water to the mix without carefully measuring the water, and always remember that the amount of water actually placed in the mix varies according to the amount of free water already in the aggregate. This means that if the aggregate is wet by a rainstorm, you may have to change the proportion of water in the mix.

3.2.2 Measuring Aggregate

The accuracy of aggregate measurement by volume depends upon the accuracy with which the amount of bulking, caused by moisture in the aggregate, can be determined. The amount of bulking varies not only with different moisture contents but also with different gradations. Fine sand, for example, is bulked more than coarse sand by the same moisture content. Furthermore, moisture content itself varies from time to time, and a small variation causes a large change in the amount of bulking. For these and other reasons, aggregate should be measured by weight rather than by volume whenever possible.

Store and measure coarse aggregate from separate piles or hoppers. This will make grading easier, keep segregation low, and ensure that each batch is uniform. The ratio of maximum to minimum particle size should not exceed 2:1 for a maximum nominal size larger than 1 inch. The ratio should not exceed 3:1 for a maximum nominal size smaller than 1 inch. A mass of aggregate with a nominal size of 1 1/2 inches to 1/4 inch, for example, should be separated into one pile or hopper containing 1 1/2 inch to 3/4 inch aggregate, and another pile or hopper containing 3/4 inch to 1/4 inch aggregate. A mass with a nominal size of 3 inches to 1/4 inch should be separated into one pile or hopper containing 3 inch to 1 1/2 inch aggregate, another containing 1 1/2 inch to 3/4 inch aggregate, and a third containing 3/4 inch to 1/4 inch aggregate.

3.2.3 Water-Cement Ratio

The major factor controlling strength, everything else being equal, is the amount of water used per bag of cement. Maximum strength is obtained by using just the amount of water, and no more, required for complete hydration of the cement. As previously mentioned, a mix of this type may be too dry to be workable. Concrete mix always contains more water than the amount required to attain maximum strength. The point to remember is that the strength of concrete decreases as the amount of extra water increases.

The specified water-cement ratio is the happy medium between the maximum possible strength of the concrete and the necessary minimum workability requirements. The strength of building concrete is expressed in terms of the compressive strength in pounds per square inch (psi) reached after a 7 or 28 day set. This is usually referred to as probable average 7 day strength and probable average 28 day strength.

3.3.0 Slump Testing

Slump testing is a means of measuring the consistency of concrete using a slump cone. The cone is made of galvanized metal with an 8 inch diameter base, a 4 inch diameter top, and a 12 inch height. The base and the top are open and parallel to each other and at right angles to the axis of the cone, shown in *Figure 6-6*. A ***tamping*** rod 5/8 inch in diameter and 24 inches long is also needed. The tamping rod should be smooth and bullet pointed. Do not use a piece of reinforcing bar (***rebar***).

Take samples of concrete for test specimens at the mixer or, in the case of ***ready mixed concrete***, from the transportation vehicle during discharge.

The sample of concrete from which test specimens are made should be representative of the entire batch. Obtain these samples by repeatedly passing a scoop or pail through the discharging stream of concrete, starting the sampling operation at the beginning of discharge, and repeating the operation until the entire batch is discharged. To counteract segregation when a sample must be transported to a test site, remix the concrete with a shovel until it is uniform in appearance. The job location from which you take the sample should be noted for future reference. In the case of paving concrete, you may take samples from the batch immediately after depositing it on the subgrade. Take at least five samples at different times, and these samples should be thoroughly mixed to form the test specimen.

Figure 6 – Slump cone and tamping rod.

When making a ***slump test***, dampen the cone and place it on a flat, moist, nonabsorbent surface. From the sample of concrete obtained, immediately fill the cone in three layers, each approximately one third the volume of the cone. In placing each scoop full of concrete in the cone, move the scoop around the edge of the cone as the concrete slides from the scoop. This ensures symmetrical distribution of concrete within the cone. Then rod in each layer with 25 strokes. Distribute the strokes uniformly over the cross section of the cone and penetrate 1” into the underlying layer. Rod the bottom layer throughout its depth.

If the cone becomes overfilled, use a straightedge to strike off the excess concrete flush with the top. Immediately remove the cone from the concrete by raising it carefully in a vertical direction. Measure the slump immediately after removing the cone.

Determine the slump by measuring the difference between the height of the cone and the height of the specimen as shown in *Figure 6-7*. The slump should be recorded to the nearest 1/4” in terms of inches of subsidence of the specimen during the test.

After completing the slump measurement, gently tap the side of the mix with the tamping rod. The behavior of the concrete under this treatment is a valuable indication of the cohesiveness, workability, and placeability of the mix. In a well proportioned mix, tapping only causes it to slump lower. It doesn't crumble apart or segregate by dropping larger aggregate particles to a lower level in the mix. If the concrete crumbles apart, it is oversanded.

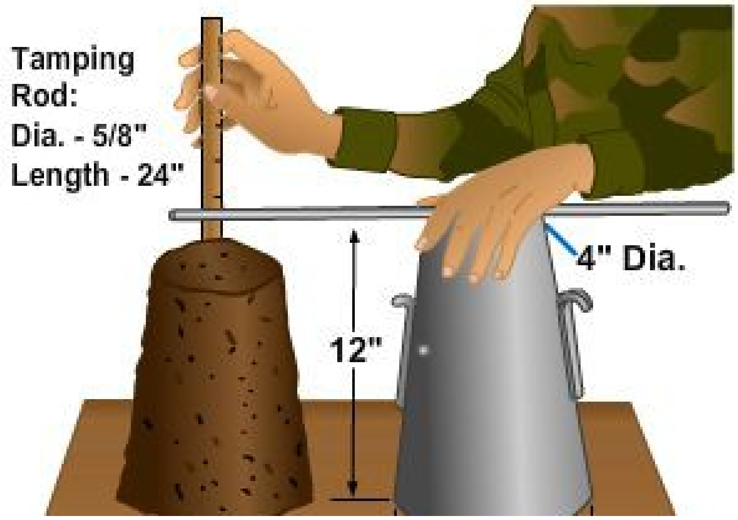


Figure 7 – Measuring the slump.

If it segregates, it is undersanded.

3.4.0 Test Cylinders

There are two reasons to make and test cylinders:

1. Determine if the concrete meets the design requirements for specified compressive strength, known as **design strength check**.
2. Determine if the concrete that has been placed is of sufficient strength for the forms to be removed or for the concrete to be put into service, known as **construction site control**.

3.4.1 Making Test Cylinders

Specifications usually require at least two cylinder breaks to be averaged and reported as one "test" to provide compressive strength results, giving a better indication of the strength of the concrete. If you need to test at 7 days and 28 days, you will need to make at least 6 cylinders. You will also need one or more *hold cylinders* as backups in case the 28-day cylinders are damaged or do not come up to strength.

Most concrete test cylinders made in the United States are 6 inches in diameter and 12 inches high and are known as 6 x 12 cylinders. Sometimes other sizes such as 4 x 8 inches and 3 x 6 inches are used, but these require adjustments of the test results to equate to the 6 x 12 cylinder strengths.

There are several kinds of cylinder molds, including heavy steel molds, sheet metal molds also known as tin can molds, plastic molds, and waxed cardboard molds. Tin can, cardboard, and some plastic molds are single use molds. Heavy steel molds and some sheet metal and plastic molds are reusable, but you must be clean and oil them after each use.

After obtaining a sample of concrete according to ASTM C 172, the procedure to create test cylinders is:

Figure 8 – Filling test cylinders.

1. Make sure the cylinder molds have been cleaned and oiled as needed.
2. Place the cylinder molds on a solid base such as a concrete slab or a sheet of plywood, as shown in *Figure 6-8*.
3. For slumps greater than 3 inches: Fill each mold in three equal layers and use a standard tamping rod to rod each layer 25 times. The rod should penetrate all the way through each layer and into the previous layer about 1 inch. Tap the sides of the mold lightly to close any voids created by ***rodding***.
4. Mark each cylinder so it can be matched with the concrete in the corresponding part of the project. Make sure to record the time and date that the concrete was placed.
5. For slumps less than 1 inch: Fill each mold in two equal layers. Use an internal vibrator with a diameter of 3/4 inch to 1 1/2 inches, and insert it into the concrete at three locations. Leave the vibrator in the concrete long enough at each location to allow entrapped air to escape. Raise the vibrator slowly and tap the sides of the mold lightly.
6. For slumps between 1 and 3 inches: Fill the mold and compact the concrete either by rodding or vibrating, as described in step 3 or 4.
7. Strike off and smooth the surface of each cylinder. Cover the top

surface of each cylinder with a plate or sheet of impervious plastic as shown in *Figure 6-9*.

Figure 9 – Test cylinder on site.

3.4.2 Curing and Protecting Test Cylinders

Store test cylinders made for **design strength check** in a moist environment with a temperature of 60° to 80° F for up to 48 hours. ASTM C 31 suggests several ways to maintain the required moisture and temperature.

If the test cylinders will not be transported to the lab within 48 hours, remove the cylinders from their molds within 16 to 32 hours and keep them moist at 70° to 76° F until the time of the test. If the test cylinders are to be sent to the laboratory for standard curing within 48 hours, make sure they remain in the molds and are kept moist until they reach the lab. When the test cylinders reach the lab, the molds are removed and the specimens are placed in standard curing until the time of the test.

Accurate test results rely on care taken in handling, shipping, and storage of test cylinders. ASTM C 31 says that test cylinders must be protected from freezing and moisture loss during transportation and cushioned to prevent them from jarring. Several suggestions are to wrap the specimens in plastic or surround them with wet sand or wet sawdust. Travel time should not exceed 4 hours. Any test cylinders that are prematurely moved, accidentally dropped or kicked, or left in the field too long at the wrong temperature must be discarded.

Keep test cylinders made for **construction site control** at the jobsite temperature and give them the same curing as the concrete they represent. Specimens made to determine when a structure can be put into service should be removed from their molds at the same time the ***formwork*** is removed from the project. Test these specimens in the moisture condition resulting from the jobsite storage. Careful handling and transportation for testing are important for these test cylinders as well.

3.4.3 Testing the Cylinders

Compression tests of concrete cylinders are specified in ASTM C 39. The ends of the test cylinders are ground or capped in accordance with ASTM C 617. The ends of each test cylinder must be smooth, plane surfaces to assure even loading and accurate test results. Various commercial materials are available to cap compressive test specimens. Building codes usually define a **strength test** as the average of the results of breaking **two cylinders** made from the same sample and tested at the same designated age.

Job specifications usually require that concrete reach at least 3000 psi, 4000 psi, or some other minimum strength at 28 days. This specified compressive strength is commonly referred to as f_c'. Always use a 28-day strength test unless specifications definitely specify otherwise. Cylinders made, cured, and transported according to ASTM C 31 and tested according to ASTM C 39 must average at least as strong as the specified strength for the project.

When the test cylinders reach the age specified for test, place them in a calibrated hydraulic testing machine which applies load at a uniform rate to the flat ends. Increase the load until the cylinder fails under load. Calculate the strength of the concrete by dividing the maximum load by the area of the flat surface. If the cylinder is 6 inches in diameter and 12 inches high, and the maximum load is 90,000 pounds (lb), the strength is calculated as:

$$strength = \frac{maximum\ load}{loaded\ area}$$

Since the loaded area for a 6 inch diameter circle is 28.3 square inches (sq in):

$$strength = \frac{90{,}000\ pounds}{28.3\ square\ inch}$$

$$strength = 3180\ pounds\ per\ square\ inch$$

3.5.0 Rebound Hammer Test

Nondestructive and in-place test methods are valuable in overall quality assurance of concrete. They cannot be used to evaluate strength until laboratory studies develop correlations with traditional strength test results on concretes made with the same materials and mix proportions. Without such correlations, the nondestructive tests can serve to evaluate relative strengths of hardened concretes.

A widely used in-place test is done with a rebound hammer, frequently referred to as a Schmidt hammer, shown in *Figure 6-10*. It is a spring-controlled hammer that slideson a plunger.

Figure 10 – Rebound hammer.

When you press the plunger of the hammer against a concrete surface, the hammer retracts against the force of the spring. When the hammer retracts completely, the spring automatically releases. The hammer impacts the shoulder area of the plunger, and the spring-controlled mass rebounds. The rebound distance, known as the “rebound number,” is measured on a scale attached to the instrument.

The results of a Schmidt rebound hammer test performed according to ASTM C 805 are affected by surface smoothness; size, shape, and rigidity of the specimen; the type of coarse aggregate, and the carbonation of the concrete surface. When you recognize these limitations and calibrate the hammer for the particular materials used in the concrete, this instrument is useful to determine the relative compressive strength and uniformity of concrete in the structure.

Although rebound numbers are not a precise indication of the concrete strength, higher numbers mean greater strength compared to concretes made of the same materials and placed at about the same time.

Using the impact rebound hammer seems simple, but it is easy to get misleading readings. There are three main steps to this test procedure:

1. Press the plunger against the concrete surface until the hammer

impacts.
2. Press the button to lock the plunger.
3. Read the scale.

The operator must take the following precautions:

- The concrete surface must be dry and smooth. Use an abrasive stone or a grinder to smooth a rough surface.
- Keep the plunger at right angles to the surface.
- Take and record ten readings. No two test points should be closer together than 1 inch.
- Calculate the average reading as follows:
    1. Average the ten readings.
    2. Discard any readings that vary from the average by more than 7.
    3. Average the remaining readings.

If more than two readings vary by more than 7 from the average, discard all 10 readings and repeat the procedure.

3.6.0 Workability

A mix must be workable enough to fill the form spaces completely with the assistance of a reasonable amount of shoveling, spading, and vibrating. Since a fluid or runny mix does this more readily than a dry or stiff mix, you can see that workability varies directly with fluidity. The workability of a mix is determined by the slump test. The amount of the slump, in inches, is the measure of the concrete's workability; the more the slump, the higher the workability.

The slump can be controlled by a change in any or all of the following: gradation of aggregates, proportion of aggregates, moisture content. If the moisture content is too high, add more cement to maintain the proper water-cement ratio.

Attain the desired degree of workability by running a series of trial batches, using various amounts of fine to coarse aggregate, until producing a batch with the desired slump. Once you determine the amount of increase or decrease in fines required to produce the desired slump, alter the aggregate proportions, not the water proportion, in the field mix to conform.

If the water proportion is changed, the water-cement ratio will be upset.

Never yield to the temptation to add more water without making the corresponding adjustment in the cement content. Also, make sure that crewmembers who are spreading a stiff mix by hand do not ease their labors by this method without telling you.

As you gain experience, you will discover that adjustments in workability can be made by making very minor changes in the amount of fine or coarse aggregate. Generally, everything else remaining equal, an increase in the proportion of fines stiffens a mix, whereas an increase in the proportion of coarse loosens a mix.

NOTE

Before you alter the proportions set forth in a specification, you must find out from higher authority whether you are allowed to make any such alterations and, if you are, the permissible limits beyond which you must not go.

3.7.0 Grout

As previously mentioned, concrete consists of four essential ingredients: water, cement, sand, and coarse aggregate. The same mixture without coarse aggregate is mortar. Mortar, which is used chiefly for bonding masonry units together, is discussed in a later chapter. ***Grout*** refers to a water-sand-cement mixture. This mixture is used to plug holes or cracks in concrete, to seal joints, to fill spaces between machinery bedplates and concrete foundations, and for similar plugging or sealing purposes. The consistency of grout may range from stiff (about 4 gallons of water per sack of cement) to fluid (as many as 10 gallons of water per sack of cement) depending upon the nature of the grouting job at hand.

3.8.0 Batching

When bagged cement is used, the field mix proportions are usually given in terms of designated amounts of fine and coarse aggregate per bag (or per 94 pounds) of cement. The amount of material mixed at a time is called a batch. The size of a batch is usually designated by the number of bags of cement it contains, such as a four-bag batch, a six-bag batch, and so on.

The process of weighing out or measuring out the ingredients for a batch of concrete is called batching. When mixing is done by hand, the size of the batch depends on the number of people available to turn it with hand tools. When a machine does the mixing, the size of the batch depends on the rated capacity of the mixer. The rated capacity of a mixer is given in terms of cubic feet of mixed concrete, not of dry ingredients.

On large jobs, the aggregate is weighed out in an aggregate batching plant, usually shortened to batch plant, like the one shown in *Figure 6-11*. Whenever possible, a batch plant is located near and used in conjunction with a crushing and screening plant. A crushing and screening plant crushes stone into various particle sizes, then screens them into separate piles. In a screening plant, the aggregate in its natural state is screened by size into separate piles.

The batch plant, which is usually portable and can be taken apart and moved from site to site, is generally set up adjacent to the pile of screened aggregate. The plant may include separate hoppers for several sizes of fine and coarse aggregates, or only one hopper for fine aggregate and another for coarse aggregate. It may have one or more divided hoppers, each containing two or more separate compartments for different sizes of aggregates.

Figure 11 – Aggregate batching plant.

Each storage hopper or storage hopper compartment can be discharged into a weigh box, which can, in turn, be discharged into a mixer or a batch truck. When a specific weight of aggregate is called for, the operator sets the weight on a beam scale. The operator then opens the discharge chute on the storage hopper. When the desired weight is reached in the weigh box, the scale beam rises and the operator closes the storage hopper discharge chute then opens the weigh box discharge chute, and the aggregate discharges into the mixer or batch truck. Batch plant aggregate storage hoppers are usually loaded by clamshell equipped cranes.

4.0.0 MIXING CONCRETE

Concrete is mixed either by hand or machine. No matter which method you use, you must follow well established procedures if you expect finished concrete of good quality. An oversight in proper concrete mixing, whether through lack of competence or inattention to detail, cannot be corrected later.

4.1.0 Mixing by Hand

A batch to be hand mixed by a couple of crewmembers should not be much larger than 1 cubic yard. The equipment required consists of a watertight metal or wooden platform, two shovels, a metal lined measuring box, and a graduated bucket for measuring the water.

The mixing platform does not need to be made of expensive materials. It can be an abandoned concrete slab or parking lot that can be cleaned after use or a wooden platform having tight joints to prevent the loss of paste. Whichever surface you use, ensure that it is cleaned prior to use and level.

Let's say your batch consists of two bags of cement, 5.5 cubic feet of sand, and 6.4 cubic feet of coarse aggregate. Mix the sand and cement together first, using the following procedure:

1. Dump 3 cubic feet of sand on the platform first, spread it out in a layer, and dump a bag of cement over it.
2. Spread out the cement and dump the rest of the sand (2.5 cubic feet) over it.
3. Dump the second sack of cement on top of the lot.

This use of alternate layers of sand and cement reduces the amount of shoveling required for complete mixing.

Personnel doing the mixing should face each other from opposite sides of the pile and work from the outside to the center. They should turn the mixture as many times as necessary to produce a uniform color throughout. When the cement and sand are completely mixed, the mixers should level off the pile and add the coarse material and mix them by the same turning method.

Next, they should trough the pile in the center. The mixing water, after being carefully measured, should be poured into the trough. The dry materials should then be turned into the water, with great care taken to ensure that none of the water escapes. When all the water has been absorbed, the mixing should continue until the mix is of a uniform consistency. Four complete turnings are usually required.

4.2.0 Mixing by Machine

The size of a concrete mixer is designated by its rated capacity. As mentioned earlier, the capacity is expressed in terms of the volume of mixed concrete, not of dry ingredients the machine can mix in a single batch. Rated capacities run from as small as 2 cubic feet to as large as 7 cubic yards (189 cubic feet.) In the Naval Construction Forces (NCFs), the most commonly used mixer is the self-contained Model 11-S, shown in *Figure 6-12*, with a capacity of 16 cubic feet (plus a 10 percent overload.)

Figure 12 –Model 11-S concrete mixer.

The production capacity of the 11-S mixer varies from 5 to 10 cubic yards per hour, depending on the efficiency of the personnel. Aggregate larger than 3 inches will damage the mixer. The mixer consists of a frame equipped with wheels and towing tongue (for easy movement), an engine, a power loader skip, mixing drum, water tank, and an auxiliary water pump. The mixer may be used as a central mixing plant.

4.2.1 Charging the Mixer

Concrete mixers may be charged by hand or with the mechanical skip.

Before loading the mechanical skip, remove the towing tongue. Then load cement, sand, and gravel and dump them into the mixer together while the water runs into the mixing drum on the side opposite the skip. A storage tank on top of the mixer measures the mixing water into the drum a few seconds before the skip dumps. This discharge also washes down the mixer between batches. Place the coarse aggregate in the skip first, the cement next, and the sand on top to prevent excessive loss of cement as the batch enters the mixer.

4.2.2 Mixing Time

It takes a mixing machine with a capacity of 27 cubic feet or larger 1 1/2 minutes to mix a 1 cubic yard batch. Allow another 15 seconds for each 1/2 cubic yard or fraction thereof. Start the water into the drum for a few seconds before the skip begins to dump, so that the inside of the drum gets a washout before the batched ingredients go in.

Measure the mixing period from the time all the batched ingredients are in, provided that all the water is in before one fourth of the ***mixing time*** has elapsed. The time elapsing between the introduction of the mixing water to the cement and aggregates and the placing of the concrete in the forms should not exceed 1 1/2 hours.

4.2.3 Discharging the Mixer

When the material is ready for discharge from the mixer, move the discharge into place to receive the concrete from the drum of the mixer. In some cases, stiff concrete has a tendency to carry up to the top of the drum and not drop down in time to be deposited on the chute. Very wet concrete may not carry up high enough to be caught by the chute. Correct this condition by adjusting the speed of the mixer. For very wet concrete, increase the speed of the drum. For stiff concrete, slow down the drum.

4.2.4 Cleaning and Maintaining the Mixer

The mixer should be cleaned daily when it is in continuous operation or following each period of use if it is in operation less than a day. If the outside of the mixer is kept coated with oil, the cleaning process can be speeded up. Wash the outside of the mixer with a hose, and knock off all accumulated concrete. If the blades of the mixer become worn or coated with hardened concrete, the mixing action will be less efficient. Replace badly worn blades. Do not allow hardened concrete to accumulate in the

mixer drum.
The mixer drum must be cleaned out whenever it is necessary to shut down for more than 1 1/2 hours. Place a volume of coarse aggregate in the drum equal to half the capacity of the mixer and allow it to revolve for about 5 minutes. Discharge the aggregate and flush out the drum with water. Do not pound the discharge chute, drum shell, or the skip to remove aggregate or hardened concrete. Concrete will readily adhere to the dents and bumps created by such pounding. For complete instructions on the operation, adjustment, and maintenance of the mixer, study the manufacturer's manual.

All gears, chains, and rollers of mixers should be properly guarded. All moving parts should be cleaned and properly serviced to permit safe performance of the equipment. When the mixer drum is being cleaned, the switches must be open, the throttles closed, and the control mechanism locked in the OFF position. The area around the mixer must be kept clear.

Skip loader cables and brakes must be inspected frequently to prevent injuries caused by falling skips. When work under an elevated skip is unavoidable, shore up the skip to prevent it form falling in the event the brake fails or is accidentally released. The mixer operator must never lower the skip without first making sure that there is no one underneath.

Dust protection equipment must be issued to the crew engaged in handling cement, and the crew must wear the equipment when so engaged. Crewmembers should stand with their backs to the wind, whenever possible. This helps prevent cement and sand from being blown into their eyes and faces.

4.3.0 Handling and Transporting Concrete

When ready mixed concrete is carried by an ordinary type of carrier, such as a wheelbarrow or buggy, jolting of the carrier increases the natural tendency of the concrete to segregate.
Carriers should be equipped with pneumatic tires whenever possible, and the surface over which they travel should be as smooth as possible.

A long free fall also causes concrete to segregate. If the concrete must be discharged at a level more than 4 feet above the level of placement, it should be dumped into an elephant trunk similar to the one shown in *Figure 6-13*.

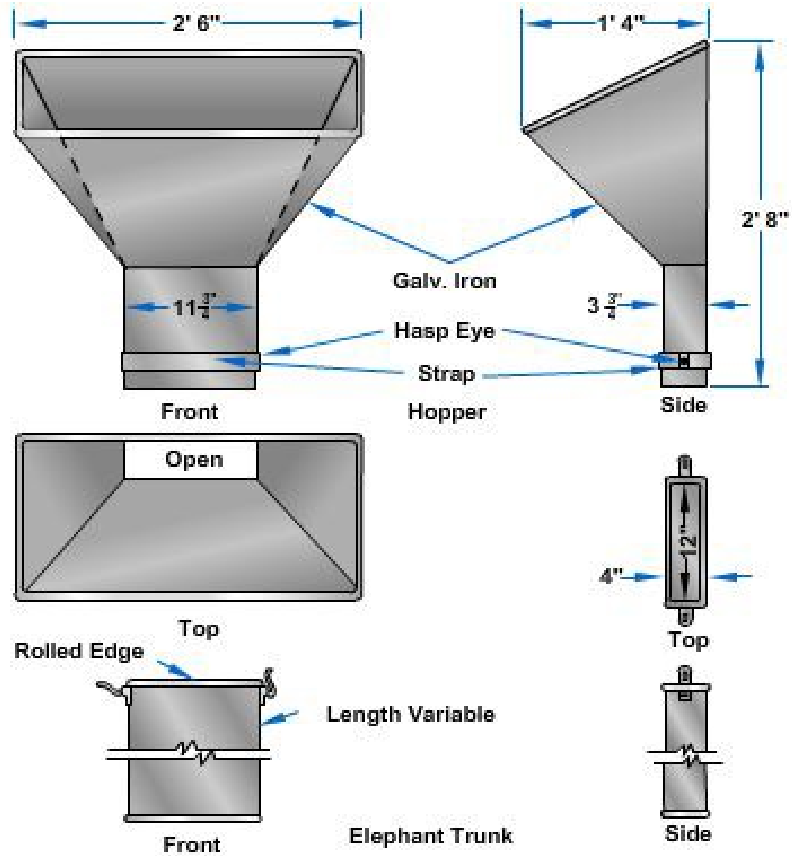


Figure 13 – Chute, or down pipe, used to check free fall of concrete.

Segregation also occurs when discharged concrete is allowed to glance off a surface, such as the side of a form or chute. Wheelbarrows, buggies, and conveyors should discharge so that the concrete falls clear.

Concrete should be transported by chute only for short distances. It tends to segregate and dry out when handled in this manner. For a mix of average workability, the best slope for a chute is about 1 foot of rise to 2 or 3 feet of run. A steeper slope causes segregation, whereas a flatter slope causes the concrete to run slowly or not at all. The stiffer the mix, the steeper the slope required. All chutes and spouting used in concrete pours should be clean and well supported by proper ***bracing*** and guys.

When spouting and chutes run overhead, the area beneath must be cleared and barricaded during placing. This eliminates the danger of falling concrete or possible collapse.

4.4.0 Ready Mixed Concrete

On some jobs, such as large highway jobs, it is possible to use a batch plant that contains its own mixer. A plant of this type discharges ready mixed concrete into transit mixers, which haul it to the construction site. The truck carries the mix in a revolving chamber much like the one on a mixer. Keeping the mix agitated en route prevents segregation of aggregate particles. A ready mix plant is usually portable so that it can follow the job along. It must be certain, of course, that a truck will be able to deliver the mix at the site before it starts to set. Discharge of the concrete from the drum should be completed within 1 1/2 hours.

4.5.0 Transit Mixed Concrete

“Transit mixing” refers to concrete that is mixed, either wet or dry, en route to a job site. A transit mix truck carries a mixer and a water tank from which the driver can, at the proper time, introduce the required amount of water into the mix. The truck picks up the dry ingredients at the batch plant together with a slip which tells how much water to introduce to the mix upon arrival at the site. The mixer drum is kept revolving en route and at the job site so that the dry ingredients do not segregate. Transit mix trucks are part of the battalion’s equipment inventory and are widely used on all but the smallest concrete jobs assigned to a battalion. A large concrete job is shown in *Figure 6-14*.

Figure 14 – Large concrete job.

5.0.0 FORMWORK

Most structural concrete is made by placing or casting plastic concrete into spaces enclosed by previously constructed forms. The plastic concrete hardens into the shape outlined by the forms. The size and shape of the formwork is always based on the project plans and specifications.

Forms for all concrete structures must be tight, rigid, and strong. If the forms are not tight, there will be excessive leakage at the time the concrete is placed. This leakage

can result in unsightly surface ridges, ***honeycombing***, and sand streaks after the concrete has set. The forms must be able to safely withstand the pressure of the concrete at the time of placement, as well as the live load, which includes personnel and equipment. Do not take shortcuts. Proper form construction material and adequate bracing in place prevent the forms from collapsing or shifting during placement of the concrete.

Forms or form parts are often omitted when a firm earth surface exists that is capable of supporting or molding the concrete. In most footings, the bottom of the footing is cast directly against the earth and only the sides are molded in forms. Many footings are cast with both the bottom and the sides against the natural earth. In these cases, the specifications usually call for larger footings. A foundation wall is often cast between a form on the inner side and the natural earth surface on the outer side.

5.1.0 Form Materials

Forms are generally constructed from earth, metal, wood, fiber, or fabric.

5.1.1 Earth

Use earthen forms in subsurface construction where the soil is stable enough to retain the desired shape of the concrete. The advantages of earthen forms are that less excavation is required and there is better settling resistance. The obvious disadvantage is a rough surface ***finish***, so the use of earthen forms is generally restricted to footings and foundations. Always take precautions to avoid collapse of the sides of trenches.

5.1.2 Metal

Use metal forms where high strength is required or where the construction is duplicated at more than one location. They are initially more expensive than wood forms, but may be more economical if they can be reused repeatedly. Originally, all prefabricated metal forms were made of steel. These forms were heavy and hard to handle. Aluminum forms, which are lightweight and easier to handle, are replacing steel.

Prefabricated metal forms are easy to erect and strip. The frame on each panel is designed so that the panels can be easily and quickly fastened and unfastened. Metal forms provide a smooth surface finish so that little concrete finishing is required after the forms are stripped. They are easy to clean, and maintenance is minimal. Care should be taken when ***stripping*** metal forms to ensure they are not damaged.

Metal wood forms are just like metal forms except for the face. It is made with a sheet of B grade exterior plywood with waterproof glue.

5.1.3 Wood

Wooden forms are by far the most common type used in building construction. They have the advantage of economy, ease in handling, ease of production, and adaptability to many desired shapes. Added economy may result from reusing form lumber later for roofing, bracing, or similar purposes. Lumber should be straight, structurally sound, strong, and only partially seasoned. Kiln dried timber has a tendency to swell when soaked with water from the concrete. If the boards are tight jointed, the swelling will cause bulging and distortion. When green lumber is used, make allowance for shrinkage, or keep the forms wet until the concrete is in place. Soft woods, such as pine, fir, and spruce, make the best and most economical form lumber since they are light, easy to work with, and available in almost every region.

Lumber that comes in contact with concrete should be surfaced at least on one side and both edges. The surfaced side is turned toward the concrete. The edges of the lumber may be square, shiplap, or tongue and groove. The latter makes a more watertight joint and tends to prevent warping.

Plywood can be used economically for wall and floor forms if it is made with waterproof glue and identified for use in concrete forms. Plywood is more warp resistant and can be reused more often than lumber. Plywood is made in 1/4, 3/8, 1/2, 9/16, 5/8 and 3/4 inch thicknesses and in widths up to 48 inches. Although longer lengths are manufactured, 8 foot lengths are the most common. The 5/8 and 3/4 inch thicknesses are most economical;

thinner sections require additional solid backing to prevent bulging. The 1/4 inch thickness is useful for forming curved surfaces.

5.1.4 Fiber

Fiber forms are prefabricated from impregnated waterproofed cardboard and other fiber materials. Successive layers of fiber are first glued together and then molded in the desired shape. Fiber forms are ideal for round concrete columns and other applications where preformed shapes are feasible since they require no form fabrication at the job site. This saves considerable time and money.

5.1.5 Fabric

Fabric forming is made of two layers of nylon fabric. These layers are woven together, forming an envelope. Structural mortar is injected into these envelopes, forming nylon encased concrete pillows. These are used to protect the shorelines of waterways, lakes and reservoirs and as drainage channel linings.

Fabric forming offers exceptional advantages in the structural restoration of bearing piles under waterfront structures. A fabric sleeve with a zipper closure is suspended around the pile to be repaired, and mortar is pumped into the sleeve. This forms a strong concrete jacket.

5.1.6 Stay-in-Place

Systems of finished stay-in-place concrete forms are used for load bearing and non- load bearing concrete walls, above and below grade applications. These systems are very versatile and can be used for a wide variety of applications. Forms are available in different wall types and can incorporate integrated adjustable door jambs, window jambs, and trim.

5.2.0 Form Design

Forms for concrete construction must support the plastic concrete until it has hardened. Stiffness is an important feature in forms. Failure to provide form stiffness may cause unfortunate results. Forms must be designed for all the weight to which they are likely to be subjected. This includes the dead load of the forms, the plastic concrete in the forms, the weight of the workmen, the weight of equipment and materials, and the impact due to ***vibration***. These factors vary with each project, but none should be ignored. Ease of erection and removal is also an important factor in the economical design of forms.

Displacement of forms due to loading and impact shock from workmen and equipment can be avoided by using platform and ramp structures independent of the formwork.

When concrete is placed in forms, it is in a plastic state and exerts hydrostatic pressure on the forms. The basis of form design is the maximum pressure developed by concrete during placing. The maximum pressure developed depends on the ***placing rate*** and the temperature. The rate at which concrete is placed affects the pressure because it determines how much ***hydrostatic head*** builds up in the form. The hydrostatic head continues to increase until the concrete takes its initial set, usually in about 90 minutes. At low temperatures, the initial set takes place much more slowly. This makes it necessary to consider the temperature at the time of placing. By knowing these two factors and the type of form material to be used, you can calculate a tentative design.

5.3.0 Form Construction

Strictly speaking, it is only those parts of the form work that directly mold the concrete that are correctly referred to as the forms. The rest of the formwork consists of various bracing and tying members. The following discussion on forms provide illustrations to help you understand the names of all the formwork members. Study these illustrations carefully so that you will understand the material in the next section.

5.3.1 Foundation Forms

The portion of a structure that extends above the ground level is called the superstructure. The portion below the ground level is called the substructure. The parts of the substructure that distribute building loads to the ground are called foundations.

Footings are installed at the base of foundations to spread the loads over a larger ground area. This prevents the structure from sinking into the ground. It’s important to remember that the footings of any foundation system should always be placed below the frost line. Forms for large footings, such as bearing wall footings, column footings, and pier footings, are called foundation forms. Footings, or foundations, are relatively low in height since their primary function is to distribute building loads. Because the concrete in a footing is shallow, pressure on the form is relatively low. A form design based on high strength and rigidity considerations is generally not necessary. *Figure 6-15* shows a foundation form for a small structure.

Figure 15 – Foundation forms.

Simple Foundation – Whenever possible, excavate the earth and use it as a mold for concrete footings. Thoroughly moisten the earth before placing the concrete. If this isnot possible, you must construct a form. Because most footings are rectangular or square, you can build and erect the four sides of the form in panels.

1. Make the first pair of opposing panels as shown in *Figure 6-16 (a)* to exact footing width.
2. Nail vertical ***cleats*** to the exterior sides of the sheathing. Use at least 1 by 2 inch lumber for the cleats, and space them 2 1/2 inches from each end of the exterior sides of the panels *(a)*, and on 2 foot centers between the ends.
3. Nail two cleats to the ends of the interior sides of the second pair of panels (*Figure 6-16 (b)*). The space between these panels should equal the footing length plus twice the sheathing thickness.
4. Nail cleats on the exterior sides of the panels *(b)* spaced on 2 foot centers.
5. Erect the panels into either a rectangle or square and hold them in place with form nails. Make sure that all reinforcing bars are in place.
6. Drill small holes on each side of the center cleat on each panel. These holes should be less than 1/2 inch in diameter to prevent paste leakage.
7. Pass No. 8 or No. 9 black annealed iron wire through these holes and wrap it around the center cleats or erect the panels into either a rectangle or square and hold them in place with form nails. Make sure that all reinforcing bars are in place.

8. Drill small holes on each side of the center cleat on each panel. These holes should be less than 1/2 inch in diameter to prevent paste leakage.
9. Pass No. 8 or No. 9 black annealed iron wire through these holes and wrap it around the center cleats of the opposing panels to hold them together as shown in *Figure 6-16*. Mark the top of the footing on the interior side of the panels with grade nails.

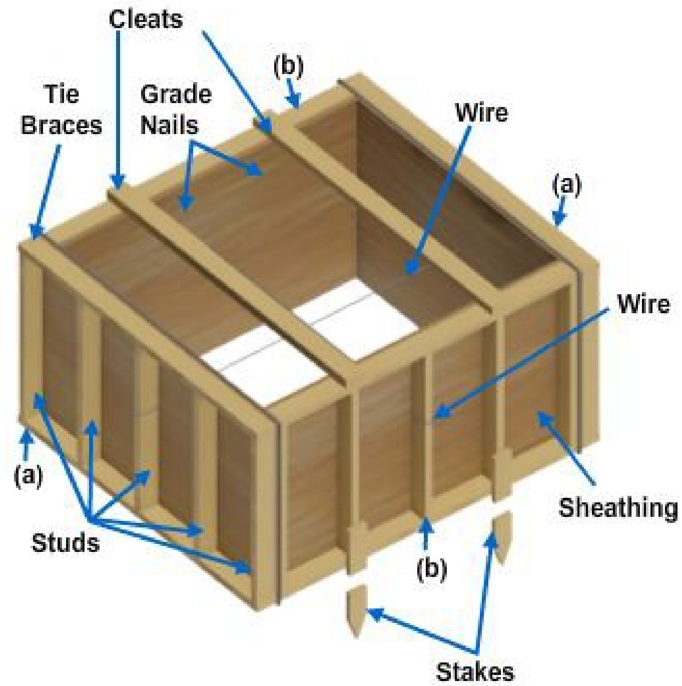


Figure 16 – Typical foundation form for a large footing.

For forms 4 feet square or larger, drive stakes against the sheathing, as shown in *Figure 6-16*. Both the stakes and the 1 by 6 tie braces nailed across the top of the form keep it from spreading apart.

If a footing is less than I foot deep and 2 feet square, you can construct the form from 1 inch sheathing without cleats. Simply make the side panels higher than the footing depth, and mark the top of the footing on the interior sides of the panels with grade

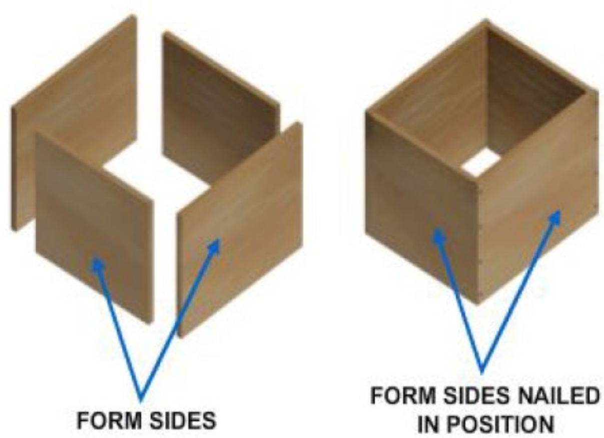


Figure 17 – Typical small footing form.

nails. Cut and nail the lumber for the sides of the form, as shown in *Figure 6-17.*

Foundation and Pier Forms Combined – You can often place a footing and a small pier at the same time. A pier is a vertical member that supports the concentrated loads of an arch or bridge superstructure. It can be either rectangular or round. Build a pier form as shown in *Figure 6-18*. The footing form should look like the one in *Figure 6-18*. You must provide support for the pier form while not interfering with concrete placement in the footing form.

Nail 2 by 4s or 4 by 4s across the footing form, as shown in *Figure 6-18*. These serve as both supports and tie braces. Nail the pier form to these support pieces.

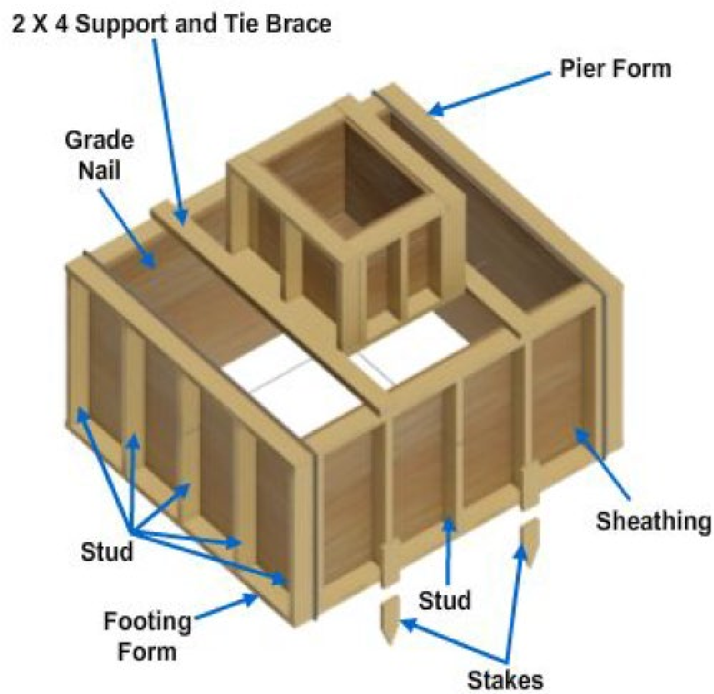


Figure 18 – Footing and pier form.

Bearing Wall Footings – *Figure 6-19* shows a typical footing formwork for a bearing wall, and *Figure 6-20* shows bracing methods for a bearing wall footing. A bearing wall, also called a load bearing wall, is an exterior wall that serves as an enclosure and also transmits structural loads to the foundation. The form sides are 2 inch lumber whose width equals the footing depth. Stakes hold the sides in place while spreaders maintain the connect distance between them. The short braces at each stake hold the form in line.

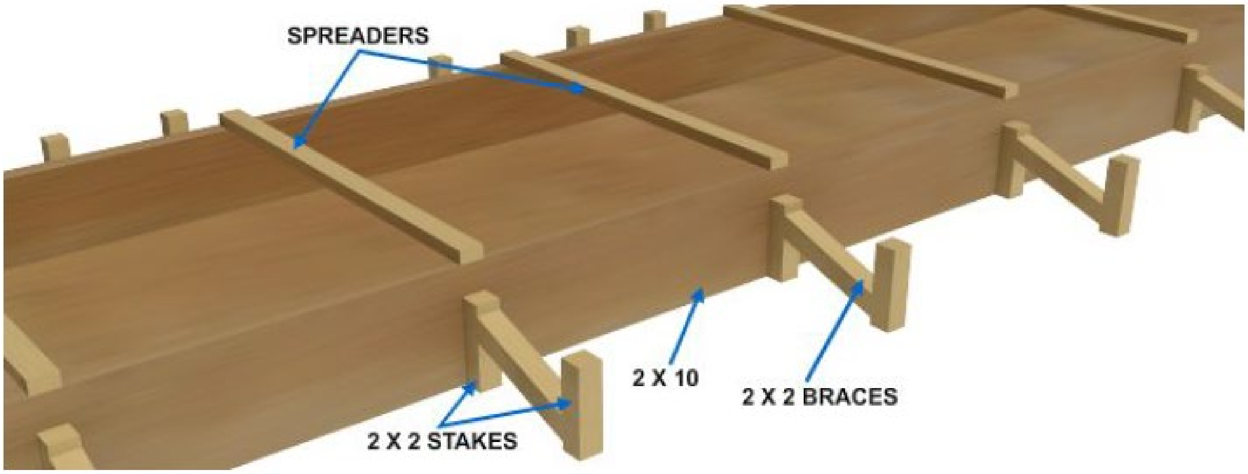


Figure 19 – Bearing wall footing form.

A keyway is made in wet concrete by placing a 2 by 2 inch board along the center of the wall footing form, shown in *Figure 6-20*. After the concrete is dry, the board is removed. This leaves an indentation, or key, in the concrete.

When you pour the foundation wall, the key provides a tie between the footing and the wall. Although not discussed in this training manual, there are several commercial keyway systems available for construction projects.

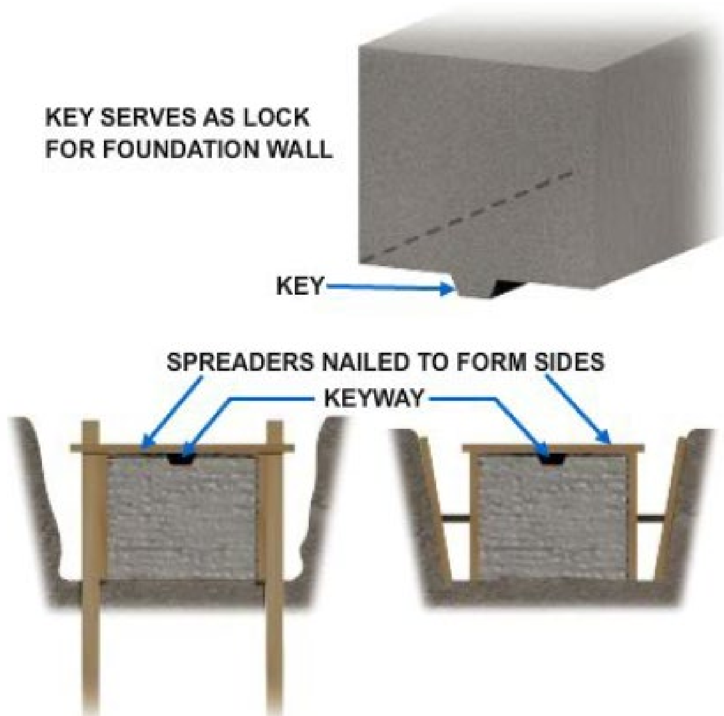


Figure 20 – Methods of bracing bearing wall footing forms and placing a keyway.

5.3.2 Columns

Square column forms are made of wood. Round column forms are made of steel or cardboard impregnated with waterproofing compound.

Figure 6-21 shows an assembled column and footing form.

1. Construct the footing forms.
2. Build the column form sides.
3. Nail the yokes to them.

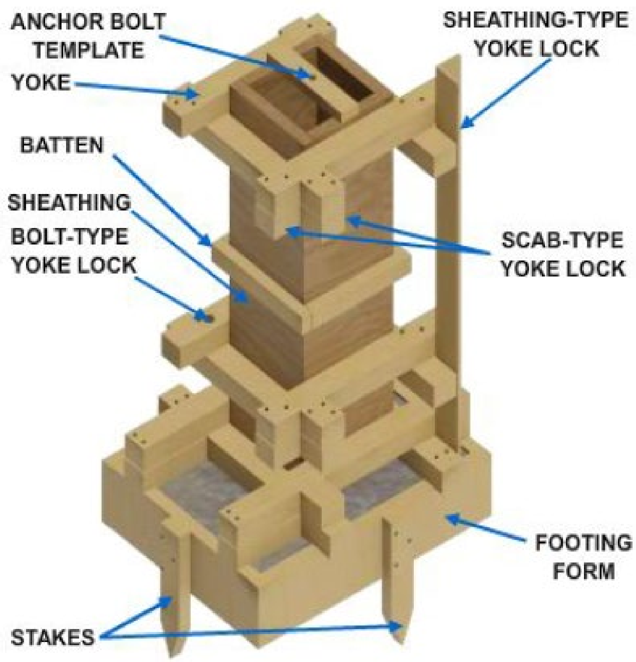


Figure 21 – Form for a concrete column.

Figure 6-22 shows a column form with two styles of yokes. *View A* shows a commercial type called a scissor clamp. *View B* shows yokes made of all-thread bolts and 2 by material. Since the rate of placing concrete in a column form is very high and the bursting pressure exerted on the form by the concrete increases directly with the rate of placing, a column form must be securely braced, as shown by the yokes in the figure.
Since the bursting pressure is greater at the bottom of the form than at the top, yokes are placed closer together at the bottom.

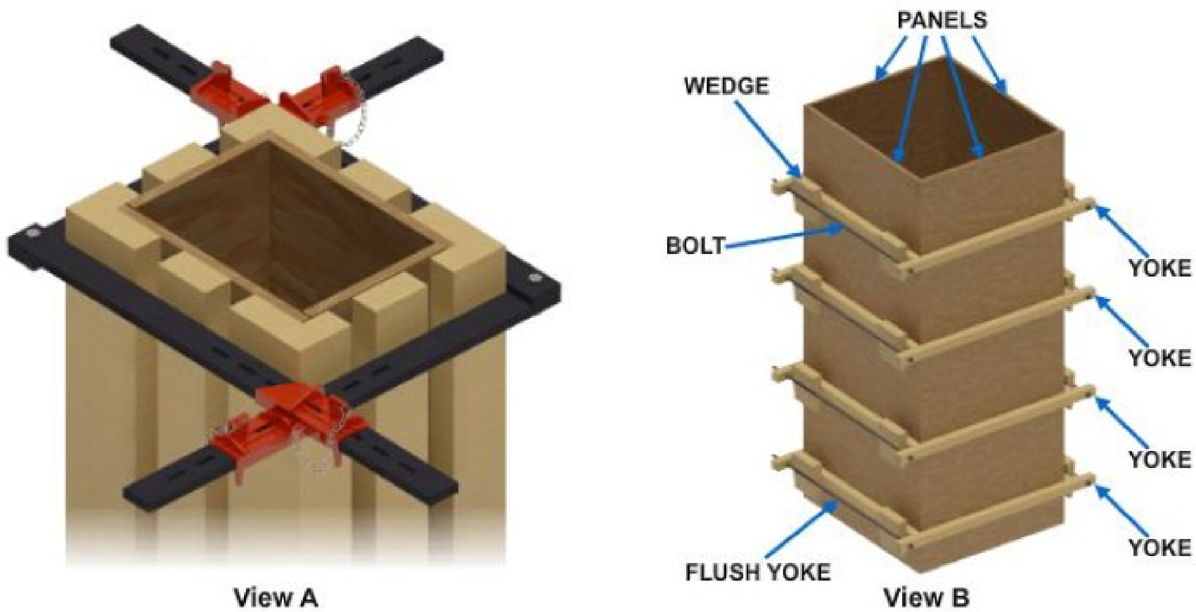


Figure 22 – Column form with with scissors clamp or yolk and wedge.

The column form should have a cleanout hole cut in the bottom to remove construction debris. Nail the pieces that you cut to make the cleanout hole to the form. You can replace them right before placing concrete in the column. The intention of the cleanout is to ensure that the surface which bonds with the new concrete is clear of all debris.

5.3.3 Wall Forms

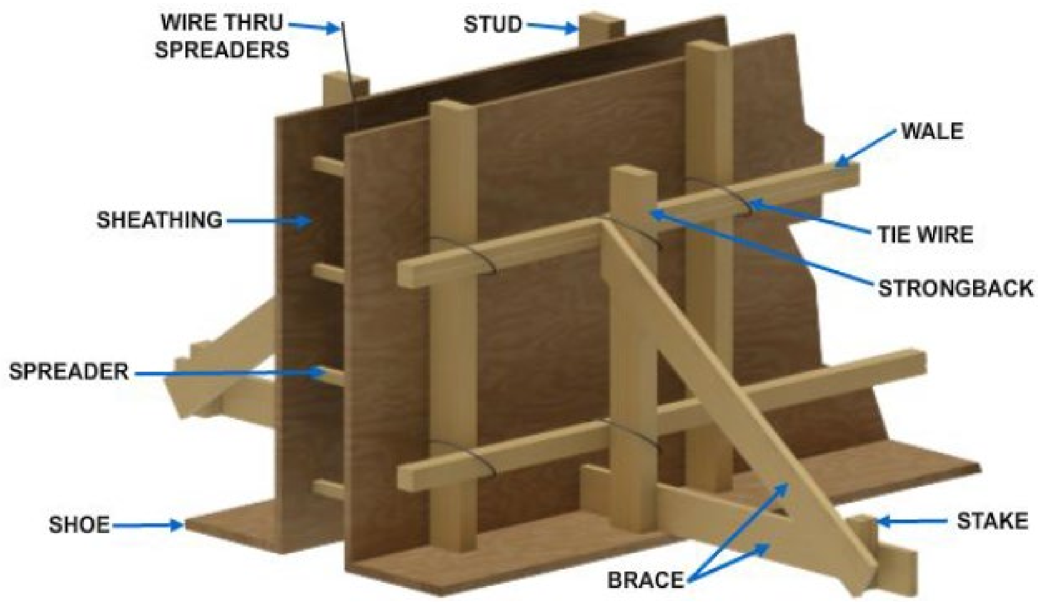
Wall forms, as shown in *Figure 6-23*, may be built in place or prefabricated, depending on the form shape and whether the form will be reused. Some of the elements that make up wooden forms are sheathing, studs, walers, braces, shoe plates, spreaders, and tie wires.

Construction sheathing forms the surfaces of the concrete. It should be as smooth as possible, especially if the finished surfaces are to be exposed. Since the concrete is in a plastic state when placed in the form, the sheathing should be watertight. Tongue and groove sheathing gives a smooth, watertight surface. You can also use plywood or hardboard, and tongue and groove sheathing is the most widely accepted construction method.

The weight of the plastic concrete causes sheathing to bulge if it is not reinforced. As a result, run studs vertically to add rigidity to the wall form. Studs are generally made from 2 by 4 or 3 by 6 material.

Studs also require reinforcing when they extend over 4 or 5 feet. Double walers supply this reinforcing. They also serve to tie prefabricated panels together and keep them in a straight line. They run horizontally and are lapped at the corners of the forms to add rigidity. Walers are usually made of the same material as the studs.

Figure 23 –Form for a concrete wall.



The shoe plate is nailed into the foundation or footing. It is carefully placed to maintain the correct wall dimension and alignment. The studs are tied into the shoe and spaced according to the correct design.

Small pieces of wood, known as spreaders, are cut the same length as the thickness of the wall and are placed between the forms to maintain proper distance between forms. Spreaders are not nailed but are held in place by friction and must be removed before the concrete covers them. Attach a wire securely to each spreader so the spreaders can be pulled out after the concrete has exerted enough pressure on the walls to allow them to be easily removed. Tie wire is designed to hold forms securely against the lateral pressure of unhardened concrete. Always use a double strand of tie wire.

Bracing – Many types of braces can be used to add stability and bracing to the forms. The most common type is a diagonal member and horizontal member nailed to a stake and to a stud or waler, as shown in *Figure 6-24*. The diagonal member should make a 30° angle with the horizontal member. You may add additional bracing to the form by placing vertical members (strongbacks) behind the walers or by placing vertical members in the corner formed by intersecting walers. Braces are not part of the form design and do not provide any additional strength.

Reinforcement – Wall forms are usually reinforced against displacement using ties. Two types of simple wire ties used with wood spreaders are shown in *Figure 6-24*. The wire is passed around the studs, the walers, and through small holes bored in the sheathing. Each spreader is placed as close as possible to the studs. *View A* shows the tie set taut by the wedge. *View B* shows the tie set taut by twisting with a small toggle.

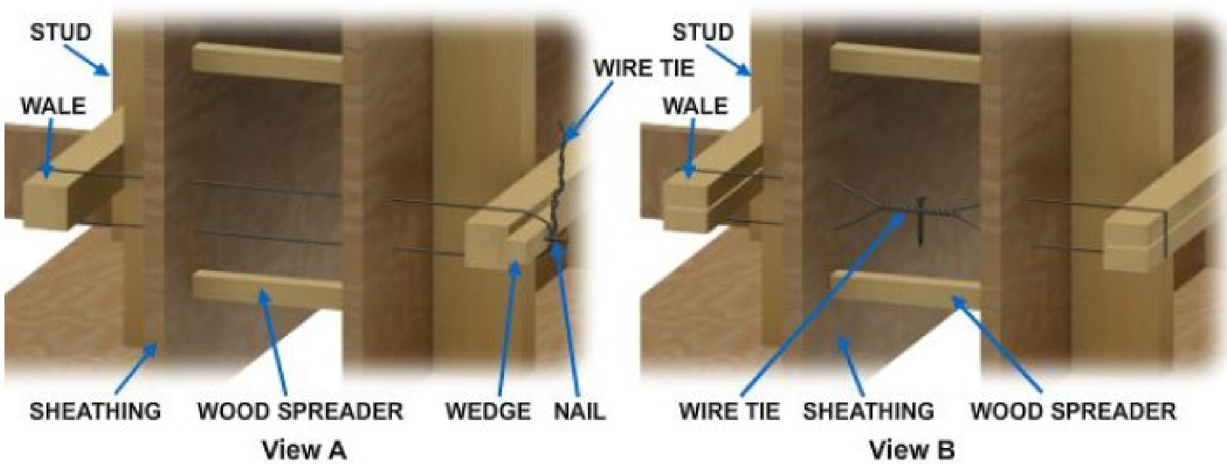


Figure 24 – Wire ties for wall forms.

As the concrete reaches the level of each spreader, knock the spreader out and remove it.

Figure 6-25 shows an easy way to remove the spreaders by drilling holes and placing a wire through them. The parts of the wire that are inside the forms remain in the concrete; the outside surplus is cut off after the forms are removed.

Wire ties and wooden spreaders have been largely replaced by various manufactured devices which combine the functions of the tie and the spreader.

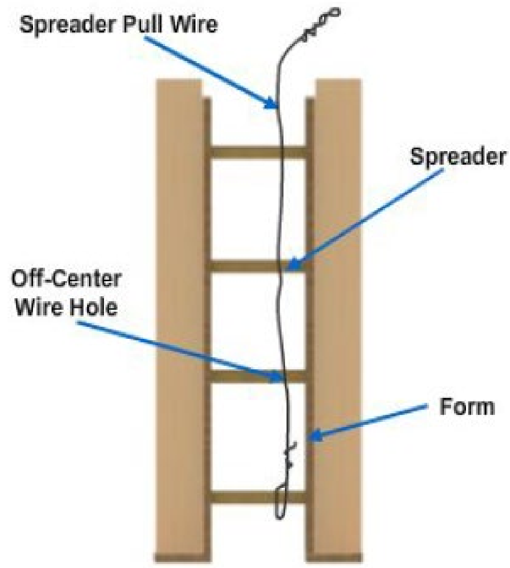


Figure 25 – Removing wood spreaders.

Figure 6-26 shows one of these. It is called a snap tie. These ties are made in various sizes to fit various wall thicknesses. The tie holders can be removed from the tie rod. The rod goes through small holes bored in the sheathing and also through the walers, which are usually doubled for that purpose. Tapping the tie holders down on the ends of the rod brings the sheathing to bear solidly against the spreader washers. You can prevent the tie holder from coming loose by driving a duplex nail in the provided hole.

After the concrete has hardened, the tie holders can be detached to strip the forms. After stripping the forms, use a special wrench to break off the outer sections of rods. The rods break off at the breaking points, located about 1 inch inside the surface of the concrete. Small surface holes remain, which can be plugged with grout if necessary.

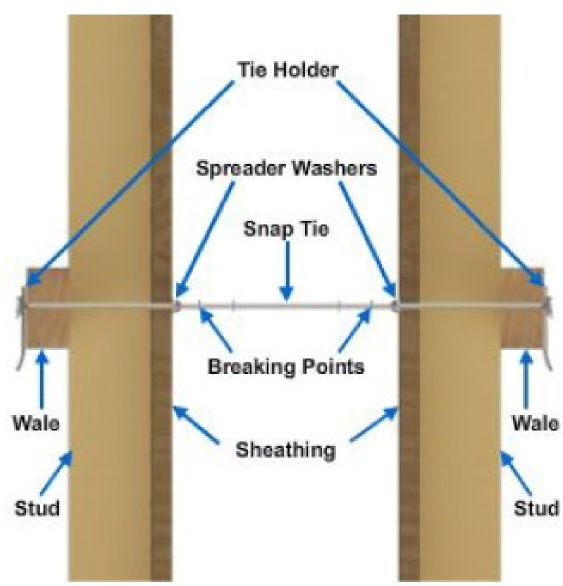


Figure 26 – Snap tie.

Determining the Load on a Snap Tie – Use these steps to determine the total load on a snap tie:

1. Figure the contributing area of form. Multiply the distance between the ties horizontally by the vertical distance between ties.
2. Multiply the contributing area of form by the unit pressure per square foot (PSFT) of the concrete on that area of form as shown in *Table 6-5*.

Table 5 – Unit Pressure per Square Foot.

Rate of Placement R. ft. per hr.				**P. maximum lateral pressure, psf for temperatures indicated.**		
	90°F	**80°F**	**70°F**	**60°F**	**50°F**	**40°F**
1	250	262	278	300	350	375
2	350	375	407	450	510	600
3	450	488	536	600	690	825
4	550	600	664	750	870	1050
5	650	712	793	900	1050	1275
6	750	825	921	1050	1230	1500
7	850	938	1050	1200	1410	1725
8	881	973	1090	1246	1466	1795
9	912	1008	1130	1293	1522	1865
10	943	1043	1170	1340	1578	1935

The following examples walk you through the process of checking the load on snap ties. The safe load on snap ties is 2,250 pounds per square foot (psf).

Example 1:

1. 8' of foam panel with snap ties at 24" on center (o.c.) (8 ties per 4' x 8' panel) as shown in *Figure 6-32*
2. Poured at 5' per hour (rate of pour) at a 70□ temperature
3. Contributing area of form
4. = 2'0" x 2'0" = 4 square feet
5. 5' rate of pour at 70 = 793 pounds of pressure per square foot (PSFT)

4 (area of form) x 793 (unit pressure per square foot.)= 3,172 psf pressure of load on snap tie

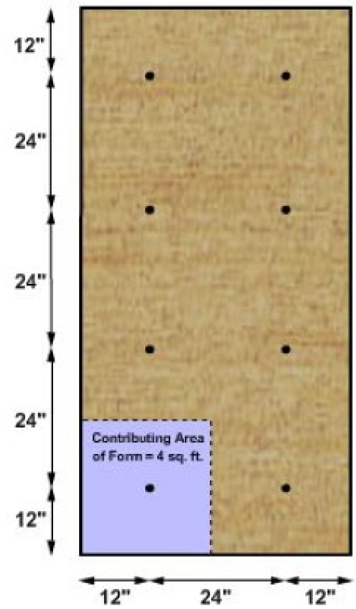


Figure 27 – Contributing area.4

CAUTION

This exceeds the safe capacity of the snap tie and must be reduced either by slowing the rate of concrete poured per hour or by reducing the snap tie spacing (increasing the number of snap ties).

Example 2:

1 8' of foam panel with snap ties at 16" o.c. (18 ties per 4' x 8' panel)

2 Poured at 5' per hour (rate of pour at a 70□ temperature)

3 Contributing area of form = 1.33 x 1.33 = 1.8 square feet

4 5' rate of pour at 70 = 793 PSFT

5 1.8 (area of form) x 793 (unit pressure per sq. ft.) = 1,427 psf pressure of load on snap tie

This is well within the 2,250 psf safe load on snap ties.

Spacing Snap Ties – Some alternatives for spacing snap ties on a 4' x 8' sheet are shown in *Figure 6-28*.

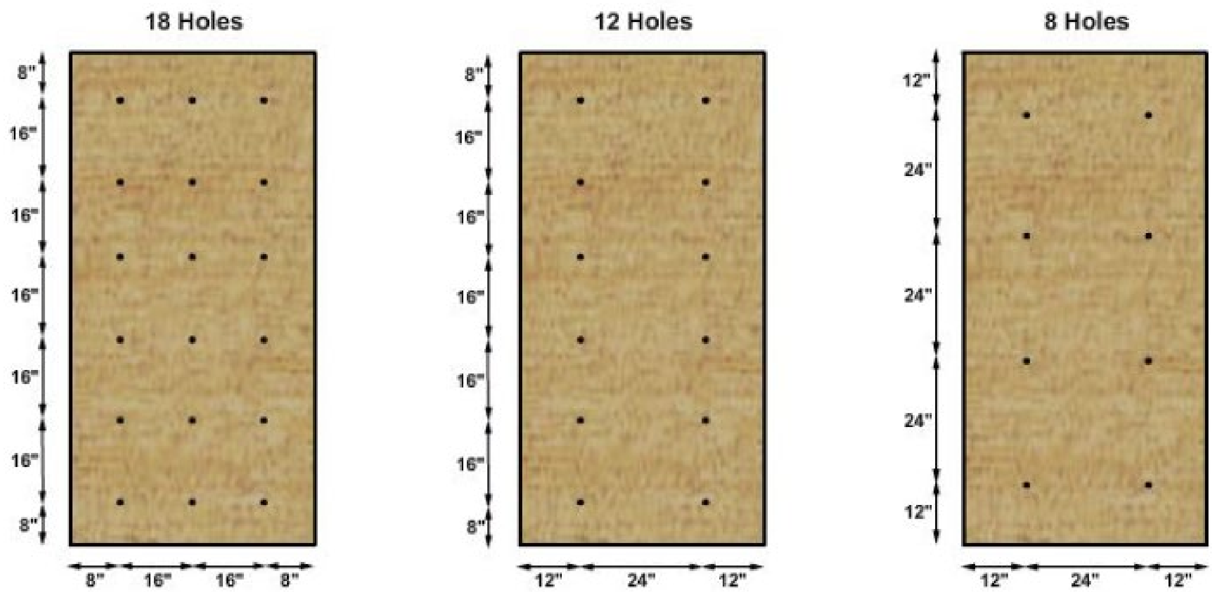


Figure 28 – Alternative snap tie spacing for 4' x 8' sheets.

Snap Tie Systems – There are a number of snap tie systems you can use; they are shown in *Figures 6-29 through 6-32*.

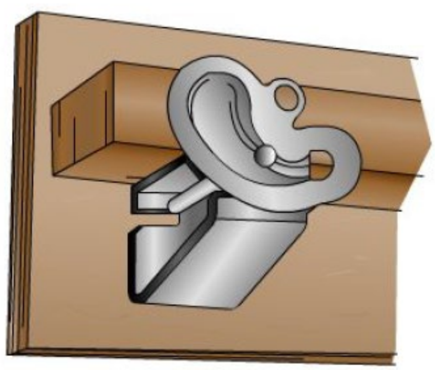


Figure 29 – Single waler system using a Jahn bracket.

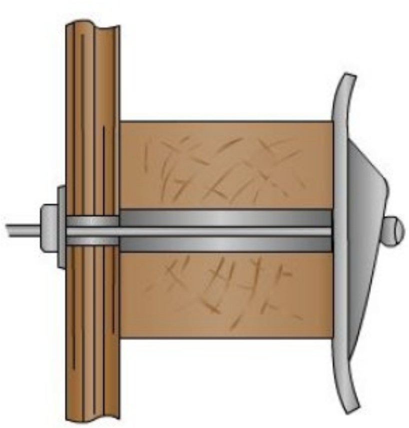


Figure 30 – 3/4" Plywood, double 2 x 4 waler with hair pin.

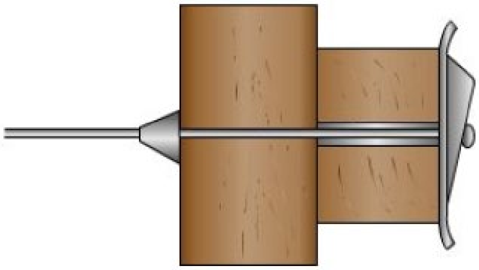


Figure 31 – 3/4" Plywood, double 2 x waler with hair pin (with strongback).

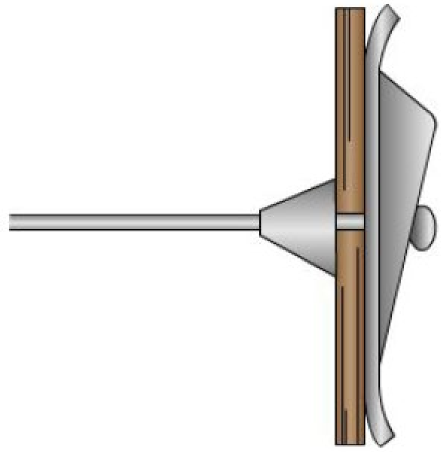


Figure 32 – Plywood (3/4" or 1 1/8") only, hair pin only.

Another type of wall form tie is the tie rod, shown in *Figure 6-33*. This rod consists of an inner section that is threaded on both ends and two threaded outer sections.

Place the inner section with the cone nuts set to the thickness of the wall between the forms, and the outer sections through the walers and sheathing and thread them into the cone nuts. Then thread the clamps on the outer sections to bring the forms to bear against the cone nuts.

After the concrete hardens, loosen the clamps and remove the outer sections of rod by threading them out of the cone nuts. After stripping the forms, remove the cone nuts from the concrete by threading them off the inner sections of the rod

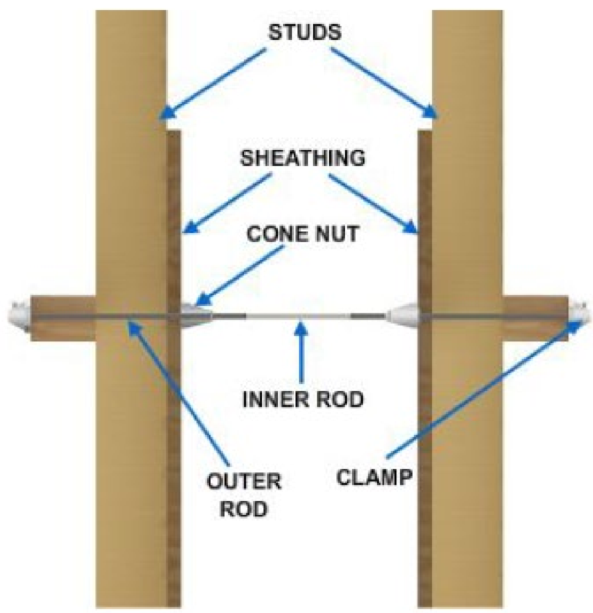


Figure 33 – Tie rod.

With a special wrench. Plug the cone shaped surface holes that remain with grout. The inner sections of the rod remain in the concrete. The outer sections and the cone nuts may be reused indefinitely.

Wall forms are usually constructed as separate panels.

1 Make the panels by first nailing sheathing to the studs.

2 Next, connect the panels, as shown in *Figure 6-34*.

Figure 6-35 shows the form details at the wall corner.

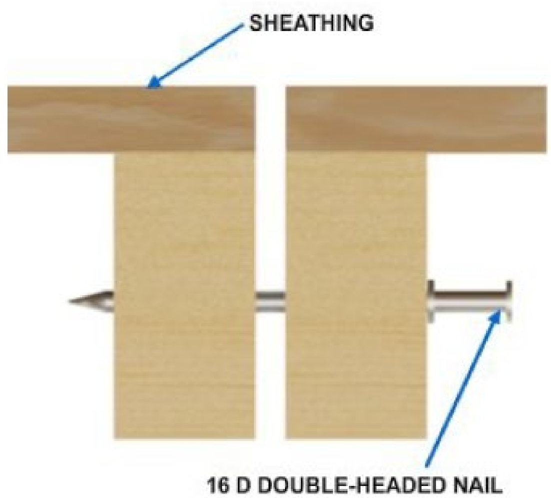


Figure 34 – Joining wall form panels together in line

Figure 35 – Joining wall form panels at a corner.

When placing concrete panel walls and columns at the same time, construct the wall form as shown in *Figure 6-36*. Make the wall form shorter than the distance between the column forms to allow for a wood strip that acts as a wedge. When stripping the forms, remove the wedge first to aid in form removal.

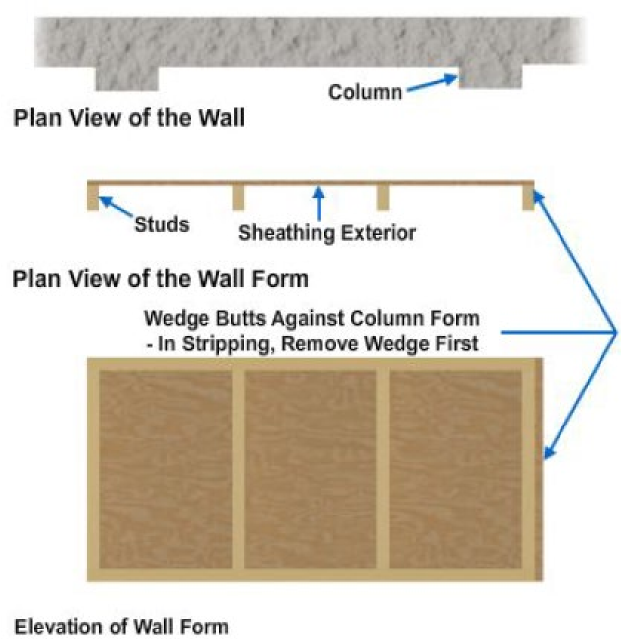


Figure 36 – Form for panel wall and columns.

5.3.4 Stair Forms

Concrete stairway forms require accurate layout to ensure accurate finish dimensions for the stairway. Always reinforce stairways with rebars (reinforcing bars) that tie into the floor and landing. Form them or after the concrete for the floor slab has set. Ge sure to anchor stairways formed after the slab has set to a wall or beam by tying the stairway rebars to rebars projecting from the walls or beams, or by providing a keyway in the beam or wall.

You can use various stair forms, including prefabricated forms. For moderate width stairs joining typical floors, a design based on strength considerations is generally not necessary.

Figure 6-37 shows one way to construct forms for stair widths up to and including 3 feet.

1. Make the sloping wood platform that serves as the form for the underside of the steps from 3/4 inch plywood. The platform should extend about 12 inches beyond each side of the stairs to support the stringer bracing blocks.
2. Shore up the back of the platform with 4 by 4 supports, as shown in *Figure 6-39*. The post supports should rest on wedges for easy adjustment and removal.
3. Cut 2 by 12 planks for the side stringers to fit the treads and risers.
4. Bevel the bottom of the 2 by 12 risers for easy form removal and finishing.

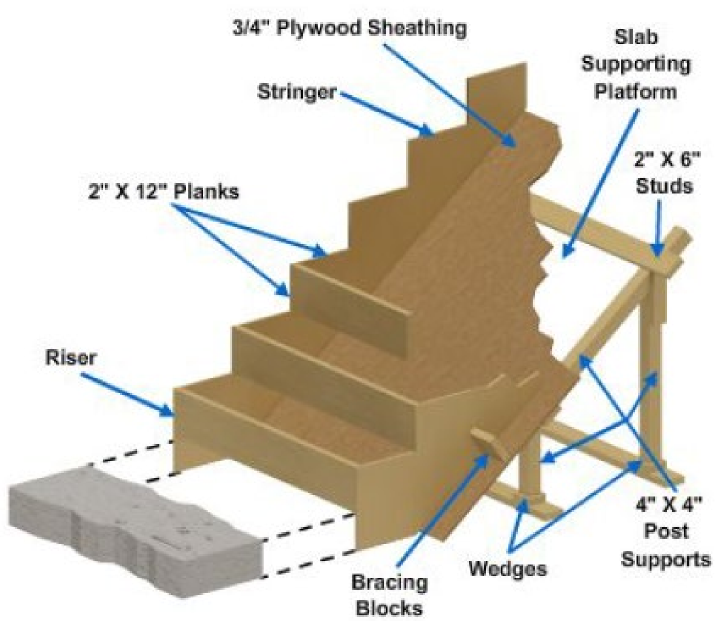


Figure 37 – Stairway form.

5.3.5 Beams and Girders

The type of construction used for beam and girder forms depends upon whether the forms are to be removed in one piece or whether the sides are to be stripped and the bottom left in place until the concrete has hardened enough to permit removal of the shoring.

The latter type of form is preferred, and details for this type are shown in *Figure 6-38*. Although beam and girder forms are subjected to very little bursting pressure, they must be shored up at frequent intervals to prevent sagging under the weight of fresh concrete.

The bottom of the form should be the same width as the beam

and in one piece for the full width. The sides of the form should be 1 inch thick tongue and groove sheathing and should lap over the bottom as shown in *Figure 6-38*. Nail the sheathing to 2 by 4 inch studs placed on 3 foot centers. Nail a 1 by 4 inch piece along the studs.

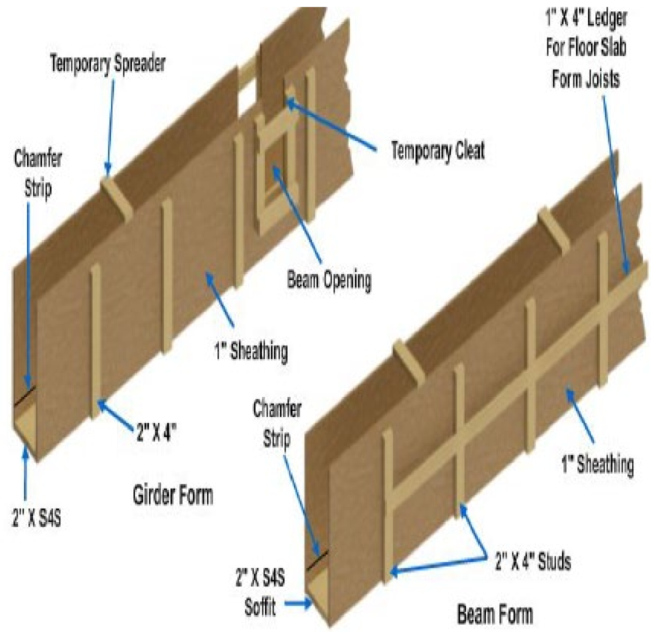


Figure 38 – Typical beam and girder form.

These pieces support the joist for the floor panel, as shown in *Figure 6-39, Detail E*. Do not nail the beam sides of the form to the bottom. They are held in position by continuous strips, as shown in *Detail E*. The crosspieces nailed on top serve as spreaders. After erection, the slab panel joists hold the beam sides in position. Girder forms are the same as beam forms except that the sides are notched to receive the beam forms. Nail temporary cleats across the beam opening when handling the girder form.

The entire method of assembling beam and girder forms is illustrated in *Figure 6-39*. The connection of the beam and girder is illustrated in *Detail D*. The beam bottom butts up tightly against the side of the girder form and rests on a 2 by 4 inch cleat nailed to the girder side. *Detail C* shows the joint between the beam and slab panel, and *Details A and B* show the joint between the girder and column. The clearances given in these details are needed for stripping and also to allow for movement caused by the weight of the fresh concrete. The 4 by 4 posts shown in *Detail E*, used for shoring the beams and girders, should be spaced to provide support for the concrete and forms. Wedge them at the bottom to obtain proper elevation.

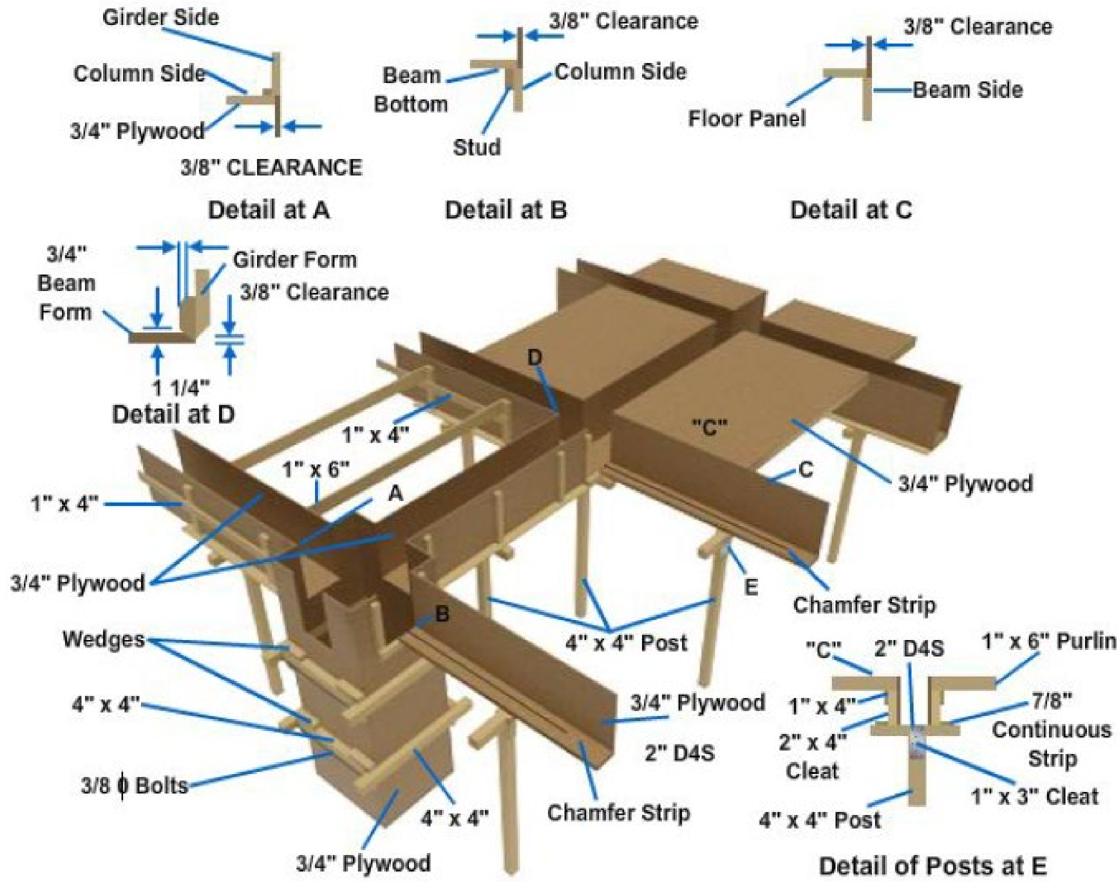


Figure 39 – Assembly of beam and floor forms.

Figure 6-40 shows how the same type of forming can be done by using quick beams, scaffolding, and I-beams, if they are available. This type of system can be set up and taken down in minimum time.

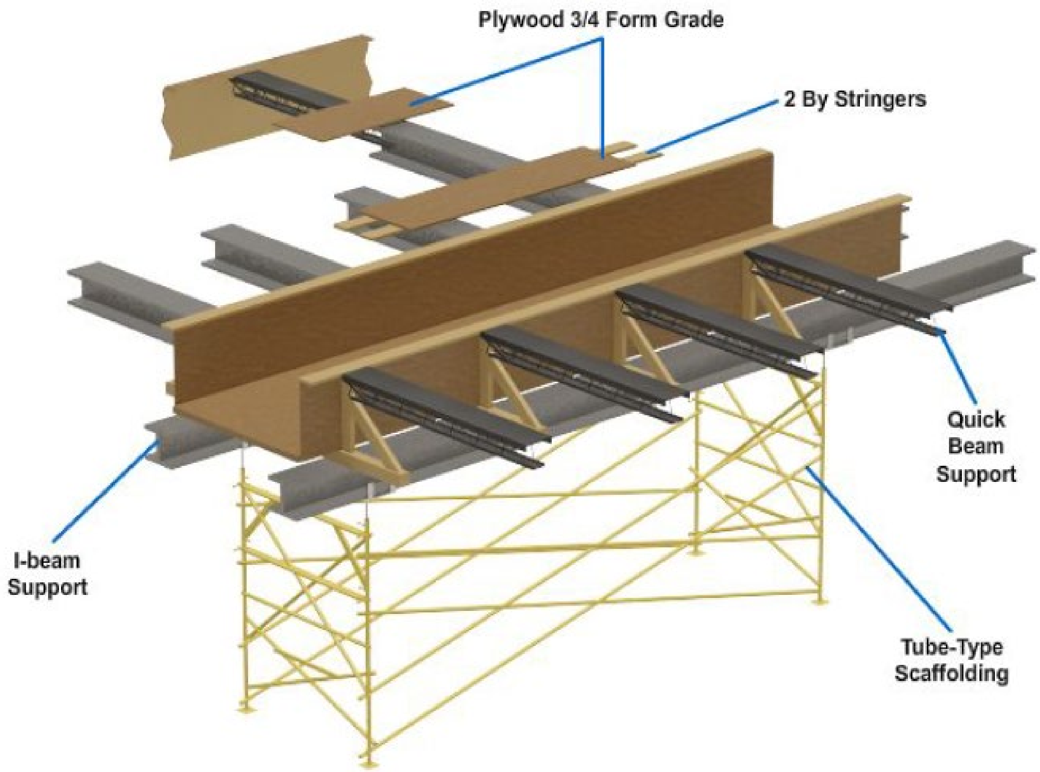


Figure – 40 – Beam and floor forms.

5.3.6 Oiling and Wetting Forms

Never use oils or other form coatings that may soften or stain the concrete surface, prevent the wet surfaces from water curing, or hinder the proper functioning of sealing compounds used for curing. If you cannot obtain standard form oil or other form coating, you can wet the forms to prevent sticking in an emergency.

Oil for Wood Forms – Before placing concrete in wood forms, treat the forms with a suitable form oil or other coating material to prevent the concrete from sticking to them. The oil should penetrate the wood and prevent water absorption. Almost any light bodied petroleum oil meets these specifications. On plywood, shellac works better than oil in preventing moisture from raising the grain and detracting from the finished concrete surface. Several commercial lacquers and similar products are also available for this purpose. If you plan to reuse wood forms repeatedly, a coat of paint or sealing compound will help preserve the wood. Sometimes lumber contains enough tannin or other organic substances to soften the concrete surface. To prevent this, treat the form surfaces with whitewash or limewater before applying the form oil or other coating.

Oil for Steel Forms – Oil wall and steel column forms before erecting them. You can oil all other steel forms when convenient, but you should oil them before placing the reinforcing steel. Use specially compounded petroleum oils, not oils intended for wood forms. Synthetic castor oil and some marine engine oils are examples of compound oils that give good results on steel forms.

Applying Oil – The successful use of form oil depends on how you apply it and the condition of the forms. They should be clean and have smooth surfaces. Because of this, do not clean forms with wire brushes, which can mar their surfaces and cause concrete to stick. Apply the oil or coating with a brush, spray, or swab.

⚠ CAUTION ⚠

Cover the form surfaces evenly, but do not allow the oil or coating to contact construction joint surfaces or any reinforcing steel in the formwork. Remove all excess oil.

Other Coating Materials – Asphalt paint, varnish, and boiled linseed oil are also suitable coatings for forms. Plain fuel oil is too thin to use during warm weather, but mixing one part petroleum grease to three parts fuel oil provides adequate thickness.

5.3.7 Form Failure

Even when all form work is adequately designed, many form failures occur because of human error, improper supervision, or use of damaged materials. The following list highlights some, but not all, of the most common construction deficiencies that supervisory personnel should consider when working with concrete:

- Inadequately tightened or secured form ties
- Inadequate diagonal bracing of shores
- Use of old, damaged, or weathered form materials
- Use of undersized form material
- Shoring not plumb

- Failure to allow for lateral pressures on form work
- Failure to inspect form work during and after concrete placement to detect abnormal deflections or other signs of imminent failure

Formwork and other work that needs to be completed before concrete is poured has to be verified before the concrete is poured. A concrete placement clearance form, shown in *Figure 6-41*, gives a thorough checklist to fill out before delivering and ***pouring*** concrete.

There are many reasons why forms fail. It is the Builder's responsibility to ensure that the forms are correctly constructed according to design, and that proper techniques are followed.

CONCRETE PLACEMENT CLEARANCE FORM

PART I | Date
Project Number | Title | Location
Date/Time Desired | QTY | Strength (PSI)
Slump (in) ______ Max Aggregate Size ______ Admixtures ______
Type of Placement () Roof () Slab () Wall () Other
Finish Required (Type) Tolerance () +/- 1/4 in. () Other

PART II		Conforms to Requirements		Item		Conforms to Requirements	
Item	N/A	Crew-leader	QC Insp		N/A	Crew-Leader	QC Insp
Subgrade Prep				Electrical			
Elevation				Conduit inst/stubbed up			
Dimension				Sleeves (foundations)			
Compaction				Pull cords			
Capillary Barr (sand)				Mechanical			
Vapor Barrier				Sleeves (foundations)			
Misc. (Insect, Drain rack, etc.)				Sub slab piping pressure tested			
Forms				Floor Drains (elevation & location)			
Elevation							
Dimensions				Floor Cleanouts (elevation & location)			
Alignment							
Bracing				Stubups (location, type)			
Condition							
Keyways				Placing/finishing Equipment			
Water Stop				Screed Boards Set			
Embedded Items				Screed Boards Checked			
Anchor Bolts				Placing Tools Set			
Sleeves				Placing Tools Checked			
Misc.				Finishing Tools Set			
Reinforcing				Finishing Tools Checked			
Size				Curing Materials			
Location and Spacing				Testing Materials (cylinders, Slump cone, etc.) arranged For on site			
Chairs (meshups)							
Bracing							

Submitted: ______________________ Crewleader ______________ Date

Approved: ______________________ QC Inspector ______________ Date

Scheduled For: ______________________

Remarks

Figure 41 – Form for Concrete Placement Clearance.

6.0.0 REINFORCED CONCRETE

Concrete is strong under compression, but relatively weak under tension; the reverse is true for steel. When the two are combined, one makes up for the deficiency of the other. When steel is embedded in concrete in a manner that assists it in carrying imposed loads, the combination is known as reinforced concrete. The steel may consist of ***welded-wire fabric*** or expanded metal mesh, but more often, it consists of reinforcing bars, commonly known as rebar.

6.1.0 Welded Wire Fabric

Welded wire fabric, often referred to as wire mesh, comes in rolls and sheets. You must cut these to fit your individual application and tie together, or lap, them to form a continuous sheet of fabric.

Specifications and designs are usually used when wire fabric is being lapped. As a rule of thumb, one complete lap is usually sufficient with a minimum of 2 inches between laps. Whenever the rule of thumb is not allowed, use the end lap or side lap method.

In the end lap method, lap the wire mesh by overlapping one full mesh measured from the end of the longitudinal wires in one piece to the end of the longitudinal wires in the adjacent piece. Then tie the two pieces with a snap tie at 1 1/2 foot centers.

In the side lap method, place the two longitudinal side wires one alongside and overlapping the other. Then tie the two pieces with a snap tie every 3 feet.

6.2.0 Reinforcing Steel

Before placing reinforcing steel in forms, complete all form oiling. As mentioned earlier, oil or other coating should not contact the reinforcing steel in the formwork. Oil on reinforcing bars reduces the bond between the bars and the concrete. Use a piece of burlap to clean the bars of rust, scale, grease, mud, or other foreign matter. A light film of rust or mill scale is not objectionable.

Rebars must be tied together for the bars to remain in a desired arrangement during pouring. Tying is also a means of keeping laps or splices in place. Laps allow bond stress to transfer the load from one bar, first into the concrete, and then into the second bar.

6.3.0 Methods of Tying

Several types of ties can be used with rebar. Some are more effective than others. The views in *Figure 6-42* illustrate the six types used by the Seabees: (A) snap, or simple, tie, (B) wall tie, (C) double strand tie, (D) saddle tie, (E) saddle tie with twist, and (F) cross, or figure eight, tie. As a Builder, you will probably be concerned only with the snap and saddle ties. As a professional, you should be familiar with all six types.

6.3.1 Snap, or Simple, Tie

To use the snap, or simple, tie *(View A)*, simply wrap it once around the two crossing bars in a diagonal manner with the two ends on top. Then twist the ends together with a pair of side cutters until they are very tight against the bars. Finally, cut off the loose ends. This tie is used mostly on floor slabs.

6.3.2 Wall Tie

To make the wall tie *(View B)*, take one and one half turns around the vertical bar, then one turn diagonally around the intersection. Twist the two ends together until the connection is tight, then cut off the excess. The wall tie is used on light vertical mats of steel.

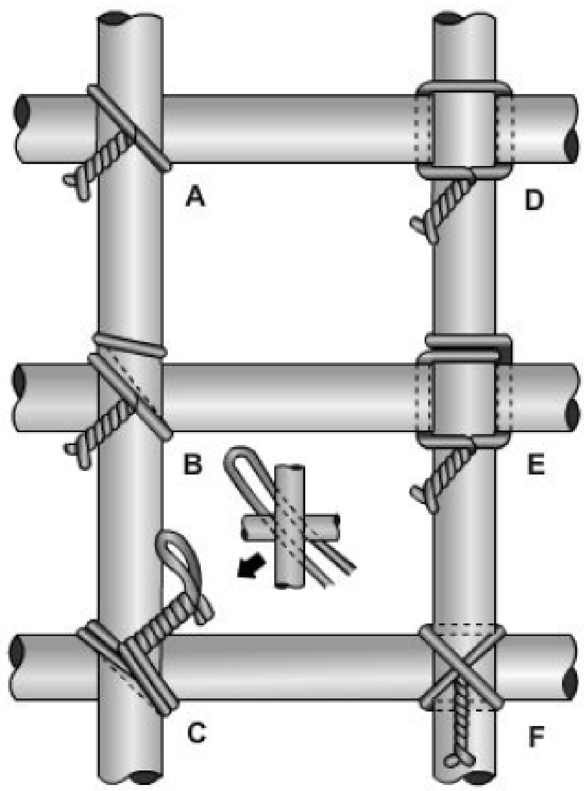


Figure 42 – Types of ties.

6.3.3 Double-Strand Single Tie

The double strand tie *(View C)* is a variation of the simple tie. It is favored in some localities and is especially used for heavy work.

6.3.4 Saddle Tie

Pass the wires of the saddle tie *(View D)* halfway around one of the bars on either side of the crossing bar and bring them squarely or diagonally around the crossing bar. Then twist the ends together and cut them off.

6.3.5 Saddle Tie with Twist

The saddle tie with twist *(View E)* is a variation of the saddle tie. Carry the tie wire completely around one of the bars, then squarely across and halfway around the other, either side of the crossing bars, and finally bring the ends together and twist them either squarely or diagonally across. The saddle tie with twist is used for heavy mats that are to be lifted by crane.

6.3.6 Cross, or Figure-Eight, Tie

The cross, or figure eight, tie *(View F)* has the advantage of causing little or no twist in the bars.

6.4.0 Location for Reinforcing Steel

The proper location for reinforcing bars is given on the drawings. To ensure that the structure can withstand the loads it must carry, place the steel in exactly the position shown. Secure the bars in position so that they will not move when the concrete is placed. Accomplish this by using the reinforcing bar supports shown in *Figures 6-43, 6- 44, and 6-45*.

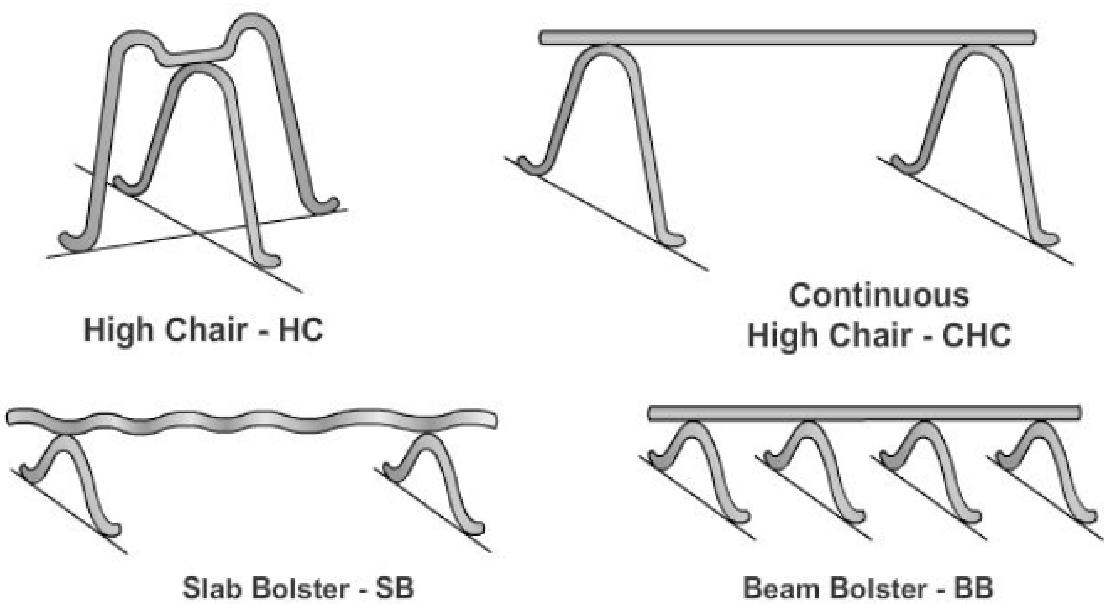


Figure 43 – Devices used to support horizontal reinforcing.

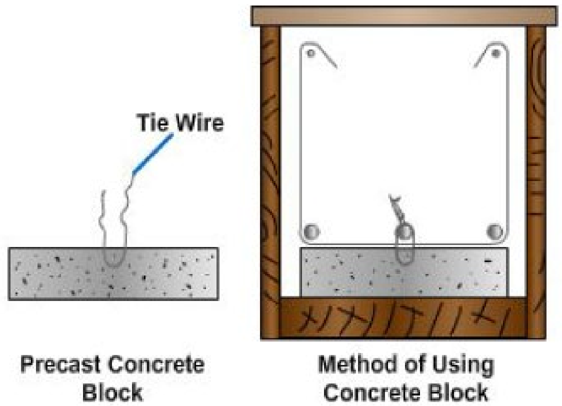


Figure 44 – Precast concrete block used for reinforcing steel support.

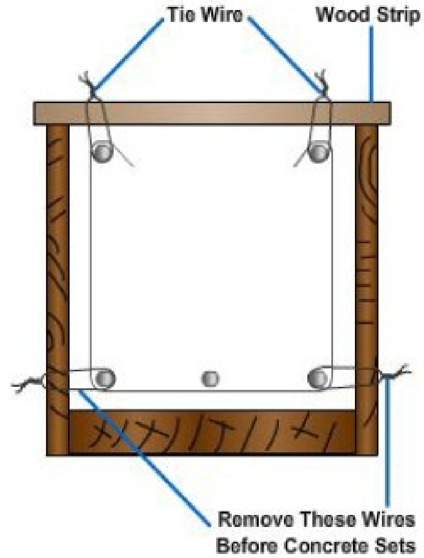


Figure 45 – Beam-reinforcing steel hung in place.

Footings and other principal structural members that are against the ground should have at least 3 inches of concrete between steel and ground.

⚠ CAUTION ⚠

If the concrete surface is to be in contact with the ground or exposed to the weather after removal of the forms, the protective covering of concrete over the steel should be 2 inches for bars larger than No. 5 and 1 1/2 inches for bars No. 5 or smaller. The protective covering may be reduced to 1 1/2 inches for beams and columns and 3/4 inch for slabs and interior wall surfaces, but it should be 2 inches for all exterior wall surfaces.

The clear distance between parallel bars in beams, footings, walls, and floor slabs should be a minimum of 1 inch, or one and one third times the largest size aggregate particle in the concrete. In columns, the clear distance between parallel bars should be a minimum of one and one half times the bar diameter, one and one half times the maximum size of the coarse aggregate, or not less than 1 1/2 inches.

The support for reinforcing steel in floor slabs is shown in *Figure 6-46*. The height of the slab bolster is determined by the concrete protective cover required.

Concrete blocks made of sand-cement mortar can be used in place of the slab bolster. Never use wood blocks for this purpose. Bar chairs, like those shown in *Figure 6-46*, are available from commercial sources in heights up to 6 inches. If you require a height greater than 6 inches, make the chair of No. 0 soft annealed iron wire. Tie the bars together at frequent intervals with a snap tie to hold them firmly in position.

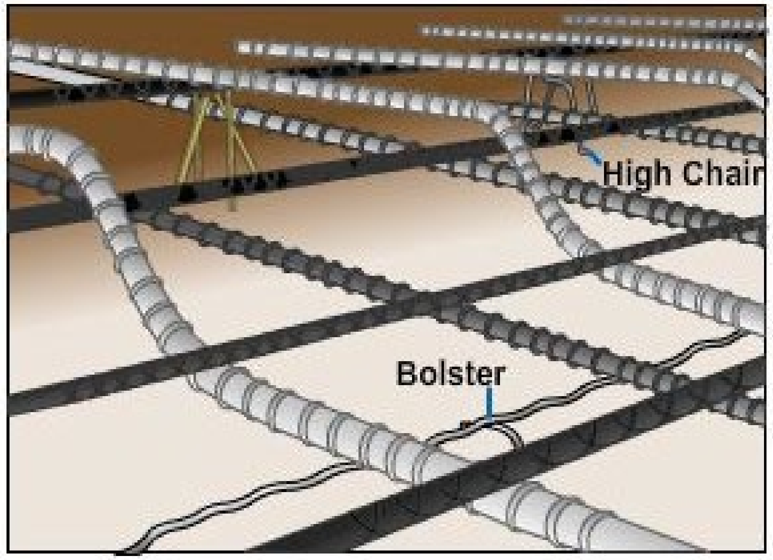
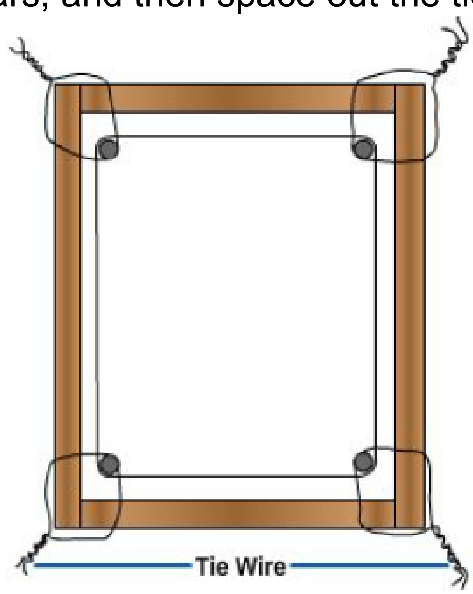


Figure 46 – Reinforcing steel for a floor slab.

Steel for column ties can be assembled into cages by laying the vertical bars for one side of the column horizontally across a couple of sawhorses. Slip the proper numbers of ties over the bars, add the remaining vertical bars, and then space out the ties as required by the placing plans. Wire a sufficient number of intersections together to make the assembly rigid. This allows you to hoist and set it as a unit.



After raising the column form, tie it to the dowels or reinforcing steel carried up from below. This holds it firmly in position at the base. Erect the column form and tie the reinforcing steel to the column form at 5 foot intervals, as shown in *Figure 6-47*.

Figure 47 – Securing a column with reinforcing steel against displacement.

The use of metal supports to hold beam reinforcing steel in position is shown in *Figure 6-48*. Note the position of the beam bolster. The stirrups are tied to the main reinforcing steel with a snap tie. Whenever possible, assemble the stirrups and main reinforcing steel outside the form and then place the assembled unit in position.

Precast concrete blocks, as shown in *Figure 6-44*, may be substituted for metal supports or, if none of the types of bar supports described above seem suitable, you may use the method shown in *Figure 6-45*.

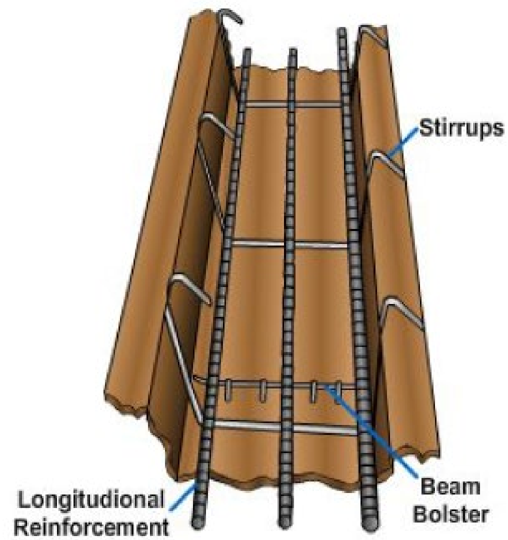
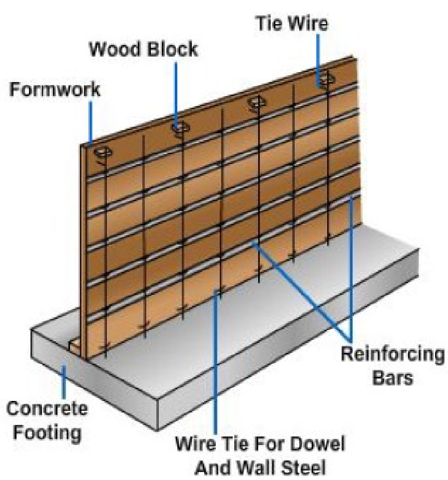


Figure 48 – Beam-reinforcing steel supported on beam bolsters.



Placement of steel in walls is the same as for columns except that the steel is erected in place and not preassembled. Tie horizontal steel to vertical steel at least three times in any bar length. Steel in place in a wall is shown in *Figure 6-49*. Remove the wood block when the form has been filled up to the level of the block. For high walls, use ties in between the top and bottom.

Figure 49 – Steel in place in a wall.

Steel is placed in footings very much as it is placed in floor slabs. You may use stones, rather than steel supports, to support the steel at the proper distance above the subgrade. Steel mats are generally preassembled and placed in small footings after the forms have been set. A typical arrangement is shown in *Figure 6-50*. Steel mats in large footings are generally constructed in place.

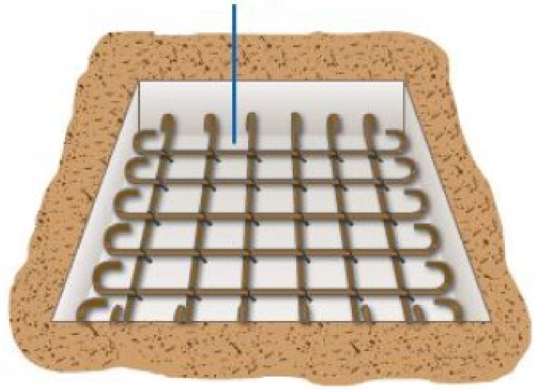


Figure 50 – Steel in place in a footing.

Welded wire fabric (WWF) as shown in *Figure 6-51* is also used as limited reinforcement for concrete footings, walls, and slabs, but its primary use is to control crack widths due to temperature changes. Form construction for each job has its peculiarities. Certain natural conditions prevail in all situations. Wet concrete always develops hydrostatic pressure and strain on forms. Be sure to properly secure all stakes, braces, walers, ties, and shebolts before placing concrete.

Figure 51 – Welded wire mesh fabric.

6.4.1 Splicing Reinforcing Bar

Because rebar is available only in certain lengths, it must be spliced together for longer runs. Where splices are not dimensioned on the drawings, lap the bars not less than 30 times the bar diameter, or not less than 12 inches, whichever is more.

The stress in a tension bar can be transmitted through the concrete and into another adjoining bar by a lap splice of proper length. The lap is expressed as the number of bar diameters. If the bar is No. 2, make the lap at least 12 inches. Tie the bars together with a snap tie as shown in *Figure 6-52.*

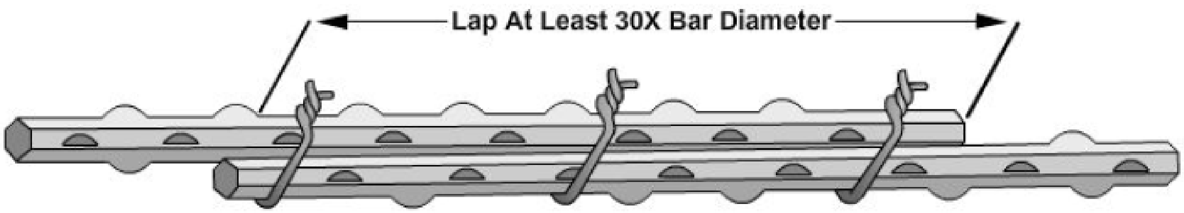


Figure 52 – Bars spliced by lapping.

7.0.0 CONCRETE CONSTRUCTION JOINTS

Concrete structures are subjected to a variety of stresses. These stresses are the result of shrinkage and differential movement. Shrinkage occurs during hydration, and differential movement is caused by temperature changes and different loading conditions. These stresses can cause cracking, spalling, and scaling of concrete surfaces and, in extreme cases, can result in failure of the structure.

7.1.0 Types of Joints

Stresses in concrete can be controlled by the proper placement of joints in the structure. We'll discuss three basic types of joints: ***isolation joints***, ***control joints***, and construction joints.

7.1.1 Isolation Joints

Isolation joints are used to separate (isolate) adjacent structural members. An example is the joint that seperates the floor slab from a column. An isolation joint allows for differential movement in the vertical and horizontal plane and expansion/contraction due to loading conditions or uneven settlement. In this context, they allow for differential movement as a result of temperature changes, as in two adjacent slabs. All isolation joints extend completely through the member and have no load transfer devices built into them. Examples of these are shown in *Figures 6-53, 6-54 and 6-55.*

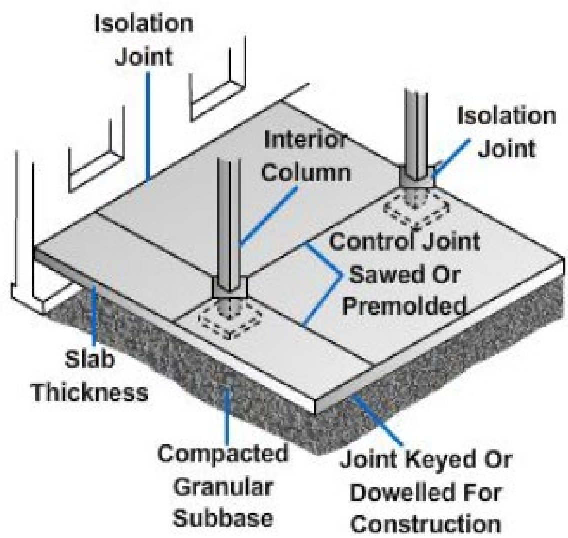


Figure 53 – Typical isolation and control joints.

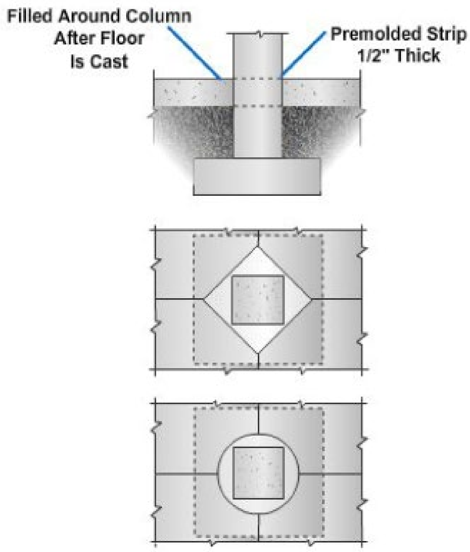


Figure 54 – Isolation joints at columns and walls.

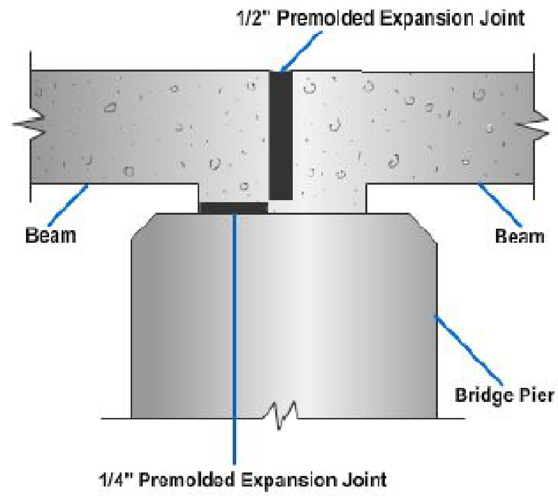


Figure 55 – Expansion/ contraction joint for a bridge.

7.1.2 Control Joints

Movement in the plane of a concrete slab is caused by drying shrinkage and thermal contraction. Some shrinkage is expected and restrained from curling; cracking will occur wherever the restraint imposes stress greater than the tensile strength. Control joints shown in *Figure 6-56* are cut into the concrete slab to create a plane of weakness. Cracking should occur at a designated place rather than randomly. These joints run in both directions at right angles to each other. Control joints in interior slabs are typically cut 1/3 to 1/4 of the slab thickness and then filled with joint filler. See *Table 6-6* for suggested control joint spacings. Temperature steel (welded wire fabric) can be used to restrict crack width.

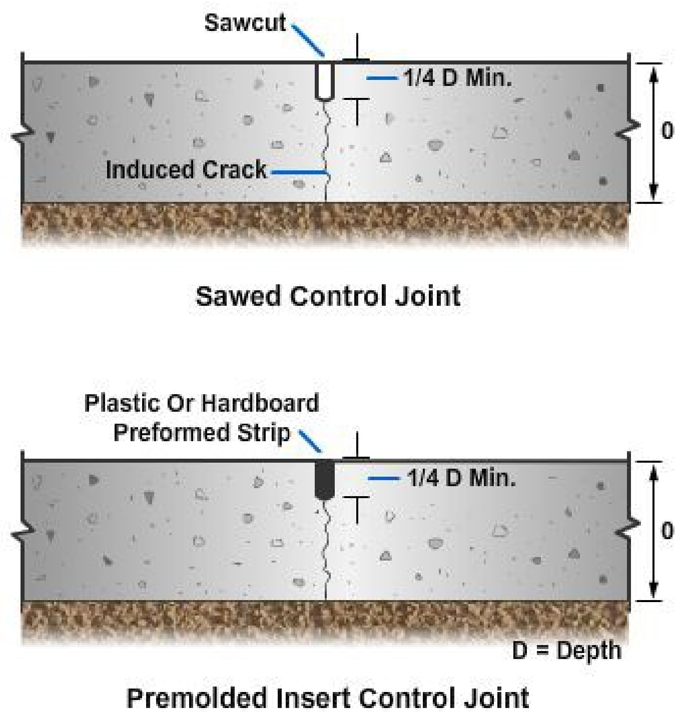


Figure 56 – Control joints.

Table 6 – Suggested Spacing of Control Joints

Slab Thickness (in.)	Less than 3/4 in. Aggregate: Spacing (ft.)	Larger than 3/4 in. Aggregate: Spacing (ft.)	Slump Less than 4 in.: Spacing (ft.)
5	10*	13	15
6	12	15	18
7	14	18	21
8	16	20	24
9	18	23	27
10	20	25	30

In driveways and sidewalks, space contraction joints at intervals about equal to the slab width. Drives and walks wider than 10 to 12 feet should have a longitudinal joint down the center. In patio slabs, joints should not be more than 10 ft apart in both directions.

As with floor slabs, make the panels as nearly square as possible. As a general rule, the smaller the panel, the less likelihood of random cracking.

Contraction joints should also be located at re-entrant corners; otherwise cracks are likely to radiate from the corners. The part of a concrete slab within a very sharp corner is likely to crack. Avoid such sharp corners if possible, but if you cannot avoid them, make sure that the subgrade is well compacted and locate contraction joints where cracking is most likely to occur. Reinforcing steel is sometimes added to hold cracks closed tight at sharp or re-entrant corners.

Surface irregularities along the plane of the crack are usually sufficient to transfer loads across the joint in slabs on grade.

7.1.3 Construction Joints

Make construction joints, shown in *Figures 6-57, 6-58, 6-59, and 6-60*, where the concrete placement operations end for the day or where one structural element is cast against previously placed concrete. These joints allow some load to be transferred from one structural element to another through the use of keys or, for some slabs and pavement, dowels. Note that the construction joint extends entirely through the concrete element.

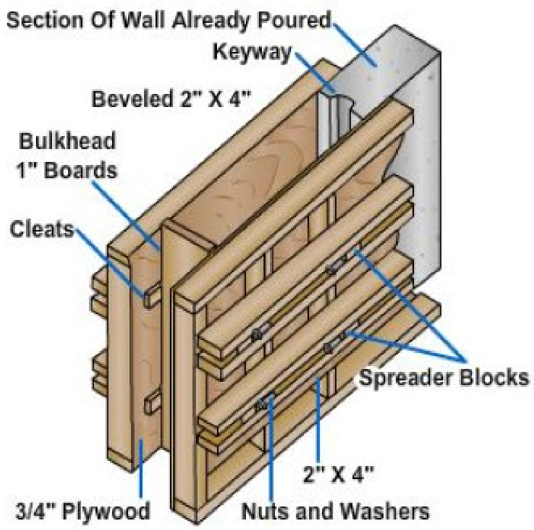


Figure 57 – Vertical bulkhead in wall using keyway.

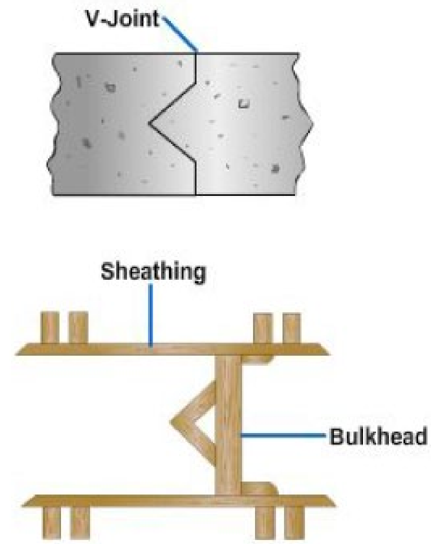


Figure 58 – Keyed wall construction joint.

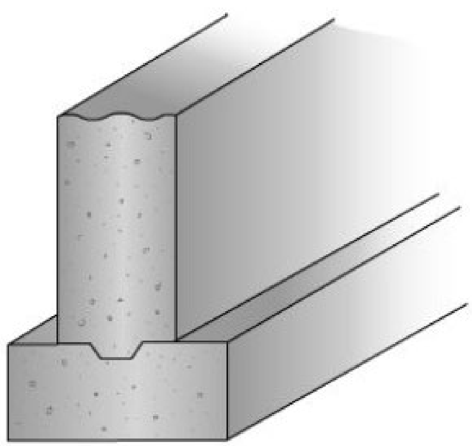


Figure 59 – Construction joint between wall and footing with

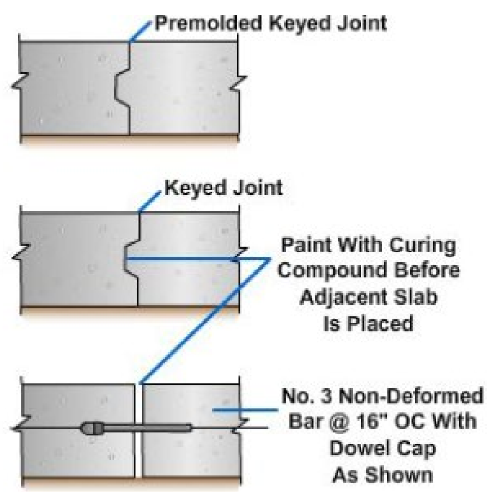


Figure 60 – Types of construction joints.

8.0.0 SAWING CONCRETE

8.1.0 The Concrete Saw

The concrete saw shown in *Figure 6-61* is used to cut longitudinal and transverse joints in finished concrete pavements. The saw is small and one person can operate it. Once the cut has been started, the machine provides its own tractive power. Use a water spray to flush the saw cuttings from the cutting area and to cool the cutting blade.

Figure 61 – Concrete saw.

Several types of blades are available. The most common blades have either diamond or Carborundum cutting surfaces. The diamond blade is used for cutting hard or old concrete; the Carborundum blade for cutting green concrete (under 30 hours old). Let's take a closer look at these two blades.

8.2.0 Diamond Blades

Diamond blades have segments made from a sintered mixture of industrial diamonds and metal powders, which are brazed to a steel disk. They are generally used to cut old concrete, asphalt, and green concrete containing the harder aggregates. Diamond blades must always be used wet. Many grades of diamond blades are available to suit the conditions of the job.

Twelve inch diameter diamond blades are the most popular size. This size makes a cut about 3 1/4 inches deep. Larger size blades are used for deeper cuts.

8.3.0 Carborundum Blades

Low cost, abrasive blades are now widely used to cut green concrete made with soft aggregates, such as limestone, dolomite, coral, or slag. These blades are made from a mixture of silicon carbide grains and a resin bond. This mixture is pressed and baked. In many cases, some of the medium hard aggregates can be cut by the step cutting method. This method uses two or more saws to cut the same joint, each cutting only a part of the total depth. This principle is also used on the longitudinal saw, which has two individually adjustable cutting heads. When a total depth of 2 1/2 inches is to be cut, the leading blade cuts the first inch and the trailing blade, which is slightly narrower, cuts the remaining depth.

Abrasive blades come in 14 and 18 inch diameters. They are made in various thicknesses to cut joints from 1/4 inch to 1/2 inch wide.

8.3.1 When to Use

When is the best time to saw green concrete? In the case of abrasive blades, there is only one answer; as soon as the concrete can support the equipment and the joint can be cut with a minimum of chipping. In the case of diamond blades, there are two factors to consider. In the interest of blade life, sawing should be delayed, but control of random cracking requires sawing at the transverse joints as early as possible. Where transverse joints are closely spaced and on large projects, cut every second or third joint initially and the rest later.

Saw joints as soon as the concrete is hard enough not to be torn or damaged by the blade, but before random cracks can form in the concrete slab. With wet cut saws, this condition usually occurs from 4 to 12 hours after finishing is complete, although sawing as late as 24 hours may be successful under some conditions.

For proper operation and maintenance of the concrete saw, follow the manufacturer’s manual.

9.0.0 PLACING CONCRETE

You cannot obtain the full value of well designed concrete without using proper placing procedures. Good concrete placing and ***consolidation*** techniques produce a tight bond between the paste and aggregate and fill the forms completely. Both of these factors contribute to the full strength and best appearance of concrete. The following are some of the principles of concrete placement:

9.1.0 Segregation

Avoid segregation during all operations, from the mixer to the point of placement, including final consolidation and finishing.

9.2.0 Consolidation

Thoroughly consolidate the concrete, working solidly around all embedded reinforcement and filling all form angles and corners.

9.3.0 Bonding

When placing fresh concrete against or upon hardened concrete, make sure that a good bond develops.

9.4.0 Temperature Control

Take appropriate steps to control the temperature of fresh concrete from mixing through final placement. Protect the concrete from temperature extremes after placement.

9.5.0 Maximum Drop

To save time and effort, you may be tempted to simply drop the concrete directly from the delivery chute regardless of form height. Unless the free fall into the form is less than 4 feet, use vertical pipes, suitable drop chutes, or baffles. *Figure 6-62* suggests several ways to control concrete fall. Good control prevents honeycombing and other undesirable results.

9.6.0 Layer Thickness

Try to place concrete in even horizontal layers. Do not attempt to puddle or vibrate it into the form. To prevent honeycombing and voids, place each layer in one operation and consolidate it before placing the next layer. This is particularly critical in wall forms containing considerable reinforcement.

Use a mechanical vibrator or a hand spading tool for consolidation. Take care not to over vibrate. This can cause segregation and a weak surface. Do not allow the first layer to take its initial set before adding the next layer. Layer thickness depends on the type of construction, the width of the space between forms, and the amount of reinforcement.

9.7.0 Compacting

(Note: This is different from soil compaction.) First, place concrete as nearly as possible into its final position. Then, work the concrete thoroughly around reinforcement and imbedded fixtures, into the corners, and against the sides of the forms. Because paste tends to flow ahead of aggregate, avoid horizontal movements that result in segregation.

9.8.0 Placing Rate

To avoid excessive pressure on large project forms, the filling rate should not exceed 4 vertical feet per hour, except for columns. Coordinate the placing and compacting so that the concrete is not deposited faster than it can be compacted properly. To avoid cracking during settlement, allow an interval of at least 4 hours, preferably 24 hours, between placing slabs, beams, or girders, and placing the columns and walls they support.

9.9.0 Placement in Wall Forms

When constructing walls, beams, or girders, place the first batches of each layer at the ends of the section, then proceed toward the center to prevent water from collecting at the form ends and corners. For walls, stop off the inside form at the construction level. Overfill the form for about 2 inches and remove the excess just before the concrete sets to ensure a rough, clean surface. Before placing the next lift of concrete, deposit a 1/2 to 1 inch thick layer of sand-cement mortar. Make the mortar with the same water content ratio as the concrete and with a 6 inch slump to prevent stone pockets and help produce a watertight joint. *View 1 of Figure 6-62* shows the proper way to place concrete in the lower portion of high wall forms. Note the different types of drop chute that can be used to place concrete through port openings and into the lower portion of the wall. Space the port openings at about 10-foot intervals up the wall. The method used to place concrete in the upper portion of the wall is shown in *View 2 of Figure 6-62*. When placing concrete for walls, be sure to remove the spreaders as you fill the forms.

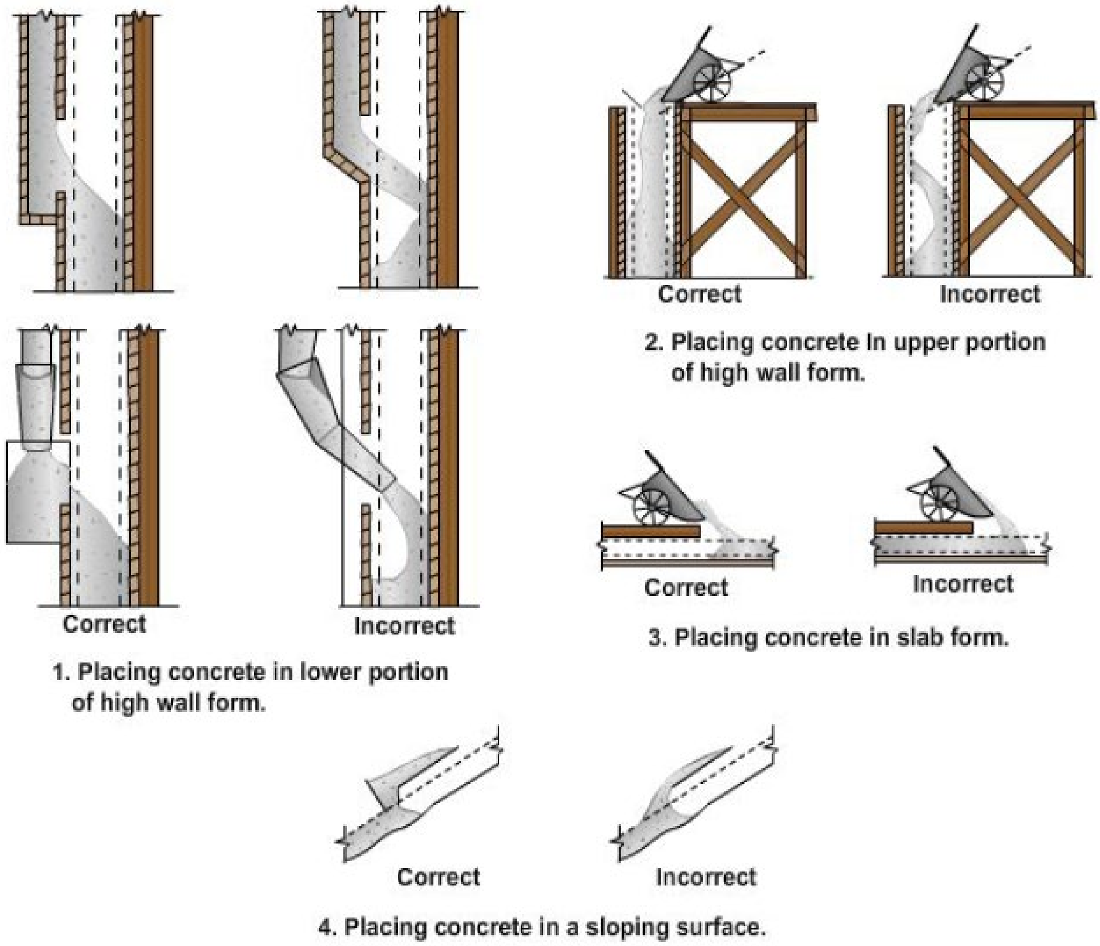


Figure 62 – Concrete placing techniques.

9.10.0 Placement of Slabs

When constructing slabs, place the concrete at the far end of the slab first, and then place subsequent batches against previously placed concrete, as shown in *View 3 of Figure 6-62*. Do not place the concrete in separate piles and then level the piles and work them together. Also, don't deposit the concrete in piles and then move them horizontally to their final position. These practices can result in segregation.

9.11.0 Placing Concrete on Slopes

View 4 of Figure 6-62 shows how to place concrete on slopes. Always deposit the concrete at the bottom of the slope first, and then proceed up the slope placing each new batch against the previous one. When consolidated, the weight of the new concrete increases the compacting of the previously placed concrete.

10.0.0 CONSOLIDATING CONCRETE

Except for concrete placed underwater, you must compact or consolidate all concrete after placement.

10.1.0 Purpose of Consolidation

Consolidation eliminates rock pockets and air bubbles and brings enough fine material both to the surface and against the forms to produce the desired finish. You can use hand tools such as spades, puddling sticks, or tampers, but mechanical vibrators are best. Any compacting device must reach the bottom of the form and be small enough to pass between reinforcing bars. The process involves carefully working around all reinforcing steel with the compacting device to assure proper embedding of reinforcing steel in the concrete. Since the strength of the concrete member depends on proper reinforcement location, be careful not to displace the reinforcing steel.

10.2.0Vibration

Vibrators consolidate concrete by pushing the coarse aggregate downward, away from the point of vibration. Vibrators allow placement of mixtures that are too stiff to place any other way, such as those having a 1 or 2 inch slump. Stiff mixtures are more economical because they require less cement and present fewer segregation or bleeding problems. Do not use a mix so stiff that it requires too much labor to place it.

10.2.1 Mechanical Vibrators

The best compacting tool is a mechanical vibrator, shown in *Figure 6-63*. The best vibrators available in engineering construction battalions are called internal vibrators because the vibrating element is inserted into the concrete.

When using an internal vibrator, insert it at approximately 18-inch intervals into air- entrained concrete for 5 to 10 seconds and into nonair-entrained concrete for 10 to 15 seconds. The exact period of time to leave a vibrator in the concrete depends on its slump. Overlap the vibrated areas somewhat at each insertion. Whenever possible, lower the vibrator into the concrete vertically and allow it to descend by gravity.

The vibrator should not only pass through the layer just placed, but penetrate several inches into the layer underneath to ensure a good bond between the layers.

Figure 63 – Using a vibrator to consolidate concrete.

Vibration does not normally damage the lower layers, as long as the concrete disturbed in these lower layers becomes plastic under the vibrating action. You know that you have consolidated the concrete properly when a thin line of mortar appears along the form near the vibrator, the coarse aggregate disappears into the concrete, or the paste begins to appear near the vibrator head. Then, withdraw the vibrator vertically at about the same gravity rate at which it descended.

Some hand spading or puddling should accompany all vibration. To avoid the possibility of segregation, do not vibrate mixes that you can consolidate easily by spading. Also, don't vibrate concrete that has a slump of 5 inches or more. Do not use vibrators to move concrete in the form.

10.2.2 Vibrating (consolidating) the Concrete

When surface vibrating slabs up to 6 inches thick, provided they are not reinforced or contain only light mesh, use low-frequency vibrating screeds — 3000 to 6000 vibrations per minute. This will provide adequate consolidation depth without creating an objectionable layer of fines at the surface. High frequency, low amplitude screeds are satrifatory when applied solely to accommodate the finishing operation. 6 to 8 inch slabs that are not reinforced may be consolidated by either surface or internal vibration.

For slabs more than 8 inches thick or thinner slabs containing embedments or substantial reinforcement, it is recommended to use an internal vibration. When an internal vibrator *(Figure 6-64),* is inserted into fresh concrete, the concrete near the vibrator tends to act like very thick liquid in the field of action area that is affected by the vibrator. By watching the way the concrete acts near the vibrator you can judge the size of the field of action. Big high-powered vibrators have larger fields of action than do small vibrators. A vibrator's field of action is larger in high slump (very wet) concrete than it is in stiffer concrete. To consolidate concrete completely, you must be sure that the fields of action overlap from one insertion point to another.

Figure 64 – Consolidation by an internal vibrator and a spading

The head of an internal vibrator should be completely immersed during vibration. For thick slabs it is possible to insert a vibrator vertically, for thinner slabs it should be inserted at an angle or even horizontally. Note that letting the vibrator contact the subgrade could contaminate the concrete with foreign material.
The vibrator should remain in the concrete until the surface of the field takes on a sheen look. There are several precautions when consolidating concrete:

- DO NOT use a vibrator to move concrete horizontally ("run the concrete") because the coarse aggregates will separate from the mortar.
- DO NOT leave a vibrator in the concrete too long in concrete mixes which have a slump of more than 3 inches, this will cause segregation. If in doubt about
- the adequacy of compaction, it is generally better to vibrate more in stiffer mixes because the danger of overvibrating stiff mixes is minimal.
- DO NOT let a vibrator run very long when it is not in concrete — it may burn out. Concrete acts as a coolant for the vibrator.
- DO NOT use an electrically powered internal vibrator without wearing good rubber gloves and rubber boots — there is a shock or burn hazard.

10.2.3 Hand Methods

Manual consolidation methods require spades, puddling sticks, or various types of tampers. To consolidate concrete by spading, insert the spade along the inside surface of the forms as shown in *Figure 6-64*, through the layer just placed, and several inches into the layer underneath. Continue spading or puddling until the coarse aggregate disappears into the concrete. Do not attempt on large placements.

11.0.0 FINISHING CONCRETE

The finishing process provides the final concrete surface. There are many ways to finish concrete surfaces, depending on the effect required. Sometimes you only need to correct surface defects, fill bolt holes, or clean the surface. Unformed surfaces may require only ***screeding*** to proper contour and elevation, or a ***broomed***, floated, or trowelled finish may be specified in the specifications.

11.1.0Screeding

The top surface of a floor slab, sidewalk, or pavement is rarely placed at the exact specified elevation. Screeding brings the surface to the required elevation by striking off the excess concrete. Two types of screeds are used in concrete finishing operations: the hand screed and the mechanical screed.

11.1.1 Hand Screed

Hand screeding requires a tool called a straightedge. This is actually a templet, usually a 2 by 4; having a straight lower edge to produce a flat surface or a curved lower edge to produce a curved surface. Move the screed back and forth across the concrete using a sawing motion, as shown in *Figure 6-65*. With each sawing motion, move the screed forward an inch or so along the forms. This forces the concrete built up against the screed face into the low spots. If the screed tends to tear the surface, as it may on air-entrained concrete due to its sticky nature, either reduce the rate of forward movement or cover the lower edge of the screed with metal. This stops tearing the tearing action in most cases.

Figure 65 – Screeding operation.

You can hand screed surfaces up to 30 feet wide, but the efficiency of this method diminishes on surfaces more than 10 feet wide. You must screed the surface a second time to remove the surge of excess concrete caused by the first screeding.

A mechanical screed as shown in *Figure 6-66* usually consists of a beam (or beams) with a gasoline engine or electric motor and a vibrating mechanism mounted in the center of the beam. Most mechanical screeds are quite heavy and usually equipped with wheels to help move them around. You may occasionally encounter lightweight screeds not equipped with wheels. These are easily lifted by two crewmembers and set back for the second pass if required.

The speed at which to pull the screed is directly related to the slump of the concrete; the less the slump, the slower the speed; the more the slump, the faster the speed. On the finishing pass of the screed, there should be no transverse (crosswise) movement of the beam; the screed is merely drawn directly forward riding on the forms or rails. For a mechanical screed, a method is provided to quickly start or stop the vibration. This is important to prevent over vibration when the screed might be standing still.

11.1.2 Mechanical Screed

The mechanical screed is being used more and more in construction for striking off concrete slabs on highways, bridge decks, and deck slabs. This screed incorporates the use of vibration and permits the use of stronger, and more economical, low-slump concrete. It can strike off this relatively dry material smoothly and quickly. The advantages of using a vibrating screed are greater density and stronger concrete. Vibrating screeds give a better finish, reduce maintenance, and save considerable time due to the speed at which they operate. Vibrating screeds are also much less fatiguing to operate than hand screeds.

Figure 66 – Mechanical screed.

Figure 67 – Concrete placement.

Concrete is usually placed 15 to 20 feet ahead of the screed and shoveled as close as possible to its final resting place. The screed is then put into operation and pulled along by two crewmembers, one at each end of the screed. It is important to keep sufficient concrete in front of the screed. Should the concrete be below the level of the screed beam, voids or bare spots will appear on the concrete surface as the screed passes over the slab. Should this occur, place a shovelful or so of concrete on the bare spot, and lift up the screed and ease it back past this spot for a second pass. In rare cases, the screed crew will work out the void or bare spot with a hand-operated bull float, rather than make a second pass with the screed.

The vibration speed will need to be adjusted for particular mixes and different beam lengths. Generally, the stiffer the mix and the longer the beam, the greater the vibration speed required. The speed at which the screed is moved also affects the resulting finish of the slab. After a few minutes of operation, a satisfactory vibration pulling speed can be established. After the vibrating screed has passed over the slab, the surface is then ready for broom or burlap finishing.

Where possible, it is advisable to lay out or engineer the concrete slab specifically for use of a vibrating screed. Lay out forms in lanes of equal widths, so that the same length screed can be used on all lanes or slabs. If possible, any vertical columns should be next to the forms, so that the screed can easily be lifted or maneuvered around the column.

There are three important advantages of using a vibrating finishing screed. First, it allows the use of low-slump concrete, resulting in stronger slabs. Second, it increases the density of the concrete, resulting in a superior wearing surface. And third, in the case of floor slabs, troweling can begin sooner since you can use drier mixes, which set up more quickly.

11.2.0 Hand Tamping

Hand tamping, or jitterbugging with a tool, as shown in *Figure 6-68*, is done after the concrete has been screeded. Hand tamping is used to compact the concrete into a dense mass and to force the larger particles of coarse aggregate slightly below the surface. This enables you to put the desired finish on the surface. Use the tamping tool only with a low slump concrete (1”-2”), and bring just enough mortar to the surface for a proper finish. After using the jitterbug, you can go directly to using the bull float.

Figure 68 – Hand tamp (Jitterbug)

11.3.0 Floating

If a smoother surface is required than the one obtained by screeding, work the surface sparingly with a wood or aluminum magnesium float, as shown in *Figure 6-69*, or with a finishing machine.

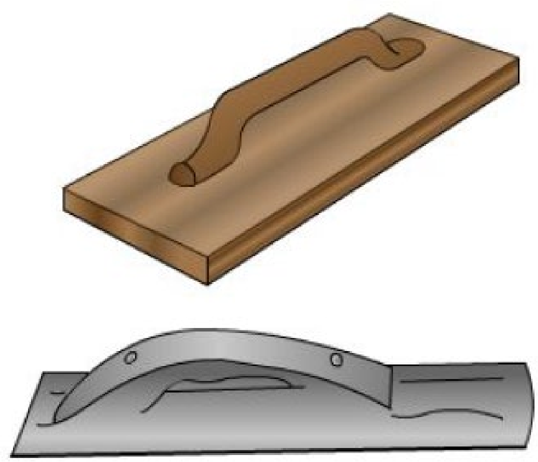


Figure 69 – Floats.

In *Figure 6-70*, the aluminum magnesium float is shown in use.

Figure 70 – Hand float in use.

A long handled wood float is used for slab construction, as shown in *Figure 6-71.* The aluminum float, which is used in the same way as the wood float, gives the finished concrete a much smoother surface. To avoid cracking and dusting of the finished concrete, begin aluminum floating when the water sheen disappears from the freshly placed concrete surface. Do not use cement or water as an aid in finishing the surface.

Figure 71 – Long handled float in use.

Floating has three purposes: (1) to embed aggregate particles just beneath the surface;
(2) to remove slight imperfections (high and low spots); and, (3) to compact the concrete at the surface in preparation for other finishing operations.

Begin bull floating immediately after screeding while the concrete is still plastic and workable. Do not overwork the concrete while it is still plastic because you may bring an excess of water and paste to the surface. This fine material forms a thin, weak layer that will scale or quickly wear off under use. To remove a coarse texture as the final finish, you usually have to float the surface a second time after it partially hardens.

11.4.0 Edging

As the sheen of water begins to leave the surface, ***edging*** should begin. Finish with an edger, as shown in *Figure 6-72*, all edges of a slab that do not abut another structure.

Figure 672 – Edger.

Figure 73 – Edger in use.

An edger dresses corners and rounds or bevels the concrete edges. Edging the slab helps prevent chipping at the corners and helps give the slab a finished appearance. *Figure 6-73* shows an edger in use.

11.5.0Troweling

If a dense, smooth finish is desired, floating must be followed by steel troweling, as shown in *Figure 6-74*. Troweling should begin after the moisture film or sheen disappears from the floated surface and when the concrete has hardened enough to prevent fine material and water from being worked to the surface. Delay this

Figure 74 – Troweling.

step as long as possible. Troweling too early tends to produce crazing and lack of durability. Too long a delay in troweling, however, results in a surface too hard to finish properly. The usual tendency is to start to trowel too soon. Troweling should leave the surface smooth, even, and free of marks and ripples. Spreading dry cement on a wet surface to take up excess water is never a good practice where a wear resistant and durable surface is required. Avoid wet spots if possible. When they do occur, do not resume finishing operations until the water has been absorbed, has evaporated, or has been mopped up.

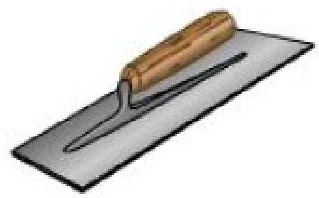


Figure 6-75 – Trowel.

11.5.1 Steel Trowel

An unslippery, fine textured surface can be obtained by troweling lightly over the surface with a circular motion immediately after the first regular troweling. In this process, kepp the trowel flat on the surface of the concrete. Where a hard steel troweled finish is required, follow the first regular troweling by a second troweling. The second troweling should begin after the concrete has become hard enough so that no mortar adheres to the trowel, and a ringing sound is produced as the trowel passes over the surface. During this final troweling, the trowel should be tilted slightly and heavy pressure exerted to thoroughly compact the surface. Hairline cracks are usually due to a concentration of water and extremely fine aggregates at the surface. This results from overworking the concrete during finishing operations. Such cracking is aggravated by drying and cooling too rapidly. Cracks that develop before troweling can usually be closed by pounding the concrete with a hand float.

11.5.2 Mechanical Troweling Machine

The mechanical troweling machine shown in Figure 6-76 is used to good advantage on flat slabs with a stiff consistency. Mechanical trowels come with a set of float blades that slip over the steel blades. With these blades, you can float a slab with the mechanical trowels. The concrete must be set enough to support the weight of the machine and the operator. Machine finishing is faster than hand finishing, but it cannot be used with all types of construction. Refer to the manufacturer’s manual for operation and maintenance of the machine you are using.

Figure 6-76 – Mechanical troweling machine.

11.6.0 Brooming

Brooming the concrete before it has thoroughly hardened can produce a nonskid surface. Brooming is carried out after the floating operation. For some floors and sidewalks where scoring is not desirable, a hair bristle brush can produce a similar finish after the surface has been troweled once. Where rough scoring is required, use a stiff broom made of steel wire or coarse fiber. When brooming, make sure that the direction of the scoring is at right angles to the direction of the traffic.

11.7.0 Grinding

When grinding of a concrete floor is specified, start it after the surface has hardened sufficiently to prevent dislodgement of aggregate particles and continue it until the coarse aggregate is exposed. The machines used should be of an approved type with stones that cut freely and rapidly. Keep the floor wet during the grinding process, and remove the cuttings by squeegeeing and flushing with water.

After the surface is ground, air holes, pits, and other blemishes are filled with a thin grout composed of one part No. 80 grain carborundum grit and one part Portland cement. Spread this grout over the floor and work it into the pits with a straightedge. Next, rub the grout into the floor with the grinding machine. When the fillings have hardened for 17 days, the floor receives a final grinding to remove the film and to give the finish a polish. Then remove all surplus material by washing thoroughly. When properly constructed of good-quality materials, ground floors are dustless, dense, easily cleaned, and attractive in appearance.

11.8.0 Sack-Rubbed Finish

A sack-rubbed finish is sometimes necessary when the appearance of formed concrete falls considerably below expectations. Perform this treatment after completing all required patching and correction of major imperfections. Thoroughly wet the surfaces and commence sack rubbing immediately.The mortar used consists of one part cement; two parts, by volume, of sand passing a No. 16 screen; and enough water so that the consistency of the mortar will be that of thick cream. It may be necessary to blend the cement with white cement to obtain a color matching that of the surrounding concrete surface. Rub the mortar thoroughly over the area with clean burlap or a sponge rubber float, so that it fills all pits. While the mortar in the pits is still plastic, ruab the surface over with a dry mix of the same material. This removes all excess plastic material and places enough dry material in the pits to stiffen and solidify the mortar. The filings will then be flush with the surface. No material should remain on the surface above the pits. ***Curing*** of the surface is then continued.

11.9.0 Rubbed Finish

A rubbed finish is required when a uniform and attractive surface must be obtained. A surface of satisfactory appearance can be obtained without rubbing by using plywood or lined forms. Do the first rubbing with coarse carborundum stones as soon as the concrete has hardened so that you do not pull out the aggregate. Then cure the concrete until final rubbing. Finer carborundum stones are used for the final rubbing.
The concrete should be kept damp while being rubbed. Any mortar used in this process and left on the surface should be kept damp for 1 to 2 days after it sets to cure properly. Keep the mortar layer to a minimum thickness as it is likely to scale off and mar the appearance of the surface.

11.10.0 Exposed Aggregate Finish

An exposed aggregate finish provides a nonskid surface. To obtain this, you must allow the concrete to harden sufficiently to support the finisher. Expose the aggregate by applying a retarder over the surface and then brushing and flushing the concrete surface with water. Since timing is important, use test panels to determine the correct time to expose the aggregate.

11.11.0 Curing Concrete

Adding water to Portland cement to form the water-cement paste that holds concrete together starts a chemical reaction that turns the paste into a bonding agent. This reaction, called hydration, produces a stone-like substance, the hardened cement paste. Both the rate and degree of hydration, and the resulting strength of the final concrete, depend on the curing process that follows placing and consolidating the plastic concrete. Hydration continues indefinitely at a decreasing rate as long as the mixture contains water and the temperature conditions are favorable. Once the water is removed, hydration ceases and cannot be restarted.

Curing is the period of time from consolidation to the point where the concrete reaches its design strength. During this period, you must take certain steps to keep the concrete moist and as near 73°F as practical. The properties of concrete; such as freeze and thaw resistance, strength, watertightness, wear resistance, and volume stability; cure or improve with age as long as you maintain the moisture and temperature conditions favorable to continued hydration.

The length of time that you must protect concrete against moisture loss depends on the type of cement used, mix proportions, required strength, size and shape of the concrete mass, weather, and future exposure conditions. The period can vary from a few days to a month or longer. For most structural use, the curing period for cast-in-place concrete is 3 days to 2 weeks. This period depends on such conditions as temperature, cement type, mix proportions, and so forth. Bridge decks and other slabs exposed to weather and chemical attack usually require longer curing periods. *Figure 6-77* shows how moist curing affects the compressive strength of concrete.

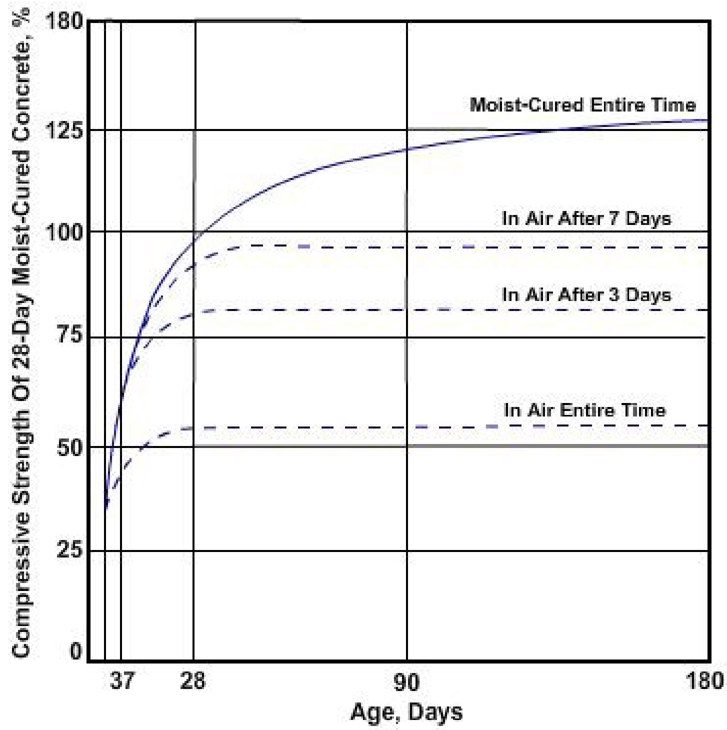


Figure 77 – Moist curing effect on compressive strength of concrete.

Table 7 – Curing Methods.

METHOD	ADVANTAGE	DISADVANTAGES
Sprinkling with Water or Covering with Burlap	Excellent results if kept constantly wet	Likelihood of drying between sprinklings; difficult on vertical walls
Straw	Insulator in winter	Can dry out, blow away, or burn
Moist Earth	Cheap but messy	Stains concrete; can dry out; removal problem
Ponding on Flat Surfaces	Excellent results, maintains uniform temperature	Requires considerable labor; undesirable in freezing weather
Curing Compounds	Easy to apply and inexpensive	Sprayer needed; inadequate coverage allows drying out; film can be broken or tracked off before curing is completed; unless pigmented, can allow concrete to get too hot
Waterproof Paper	Excellent protection, prevents drying	Heavy cost can be excessive; must be kept in rolls; storage and handling problem
Plastic Film	Absolutely watertight, excellent protection. Light and easy to handle.	Should be pigmented for heat protection; requires reasonable care and tears must be patched; must be weighed down to prevent blowing away

Methods that supply additional moisture include sprinkling and wet covers. Both these methods add moisture to the concrete surface during the early hardening or curing period. They also provide some cooling through evaporation. This is especially important in hot weather.

Sprinkling continually with water, shown in *Figure 6-78*, is an excellent way to cure concrete. If you sprinkle at intervals, do not allow the concrete to dry out between applications. The disadvantages of this method are the expense involved and the volume of water required.

Figure 78 – Sprinkling concrete with water.

Wet covers, such as straw, earth, burlap, cotton mats, and other moisture retaining fabrics, are used extensively in curing concrete. Lay the wet coverings as soon as the concrete hardens enough to prevent surface damage. Leave them in place and keep them moist during the entire curing period.

If practical, horizontal placements can be flooded by creating an earthen dam around the edges and submerging the entire concrete structure in water.

Methods that prevent moisture loss include laying waterproof paper, plastic film, or liquid membrane forming compounds, and simply leaving forms in place. All prevent moisture loss by sealing the surface.

A sheet of plastic, as shown in *Figure 6-79*, can be used to cure horizontal surfaces and structural concrete having relatively simple shapes. The plastic should be large enough to cover both the surfaces and the edges of the concrete. Wet the surface with a fine water spray before covering. Lap adjacent plastic 12 inches or more and weigh their edges down to form a continuous cover with closed joints. Leave the coverings in place during the entire curing period.

Plastic form materials are sometimes used to cure concrete. They provide lightweight, effective moisture barriers that are easy to apply to either simple or complex shapes.

Figure 79 – Curing concrete with plastic.

Some thin plastic sheets may discolor hardened concrete, especially if the surface was steel troweled to a hard finish. The coverage, overlap, weighing down of edges, and surface wetting requirements of plastic film are similar to those of waterproof paper.

Curing compounds are suitable not only for curing fresh concrete, but to further cure concrete following form removal or initial moist curing. You can apply them with spray equipment, such as hand operated pressure sprayers, to odd slab widths or shapes of fresh concrete, and to exposed concrete surfaces following form removal. If there is heavy rain within 3 hours of application, you must respray the surface. You can use brushes to apply curing compound to formed surfaces, but do not use brushes on unformed concrete because of the risk of marring the surface, opening the surface to too much compound penetration, and breaking the surface film continuity. These compounds permit curing to continue for long periods while the concrete is in use.
Because curing compounds can prevent a bond from forming between hardened and fresh concrete, do not use them if a bond is necessary.

Forms provide adequate protection against moisture loss if you keep the exposed concrete surfaces wet. Keep wood forms moist by sprinkling, especially during hot, dry weather.

11.12.0 Form Removal

Forms should, whenever possible, be left in place for the entire curing period. Since early form removal is desirable for their reuse, a reliable basis for determining the earliest possible stripping time is necessary. Some of the early signs to look for during stripping are no excessive deflection or distortion and no evidence of cracking or other damage to the concrete due to the removal of the forms or the form supports. In any event, never strip forms until the concrete has hardened enough to hold its own weight and any other weight it may be carrying. The surface must be hard enough to remain undamaged and unmarked when reasonable care is used in stripping the forms.

11.12.1 Curing Period

Haunch boards (side forms on girders and beams) and wall forms can usually be removed after 1 day. Column forms usually require 3 days before the forms can be removed. Removal of forms for soffits on girders and beams can usually be done after 7 days. Floor slab forms (over 20 foot clear span between supports) usually require 10 days before removing the forms. Specifications dictate when forms can be removed, usually after a gain of 70% of 28 day strength requirement. This is proven through a compressive strength break test.

11.12.2 Inspections

After removing the forms, inspect the concrete for surface defects. These defects may be rock pockets, inferior quality ridges at form joints, bulges, bolt holes, and form stripping damage. Experience has proved that no steps can be omitted or carelessly performed without harming the serviceability of the work. If repairs are not properly performed, the repaired area may later become loose, crack at the edges, and not be watertight. Repairs are not always necessary, but when they are, do them immediately after stripping the forms, within 24 hours.

Defects can be repaired in various ways. Let’s look at some common defects you may encounter when inspecting new concrete and how repairs can be made.

Ridges and bulges – Ridges and bulges can be repaired by careful chipping followed by rubbing with a grinding stone.

Honeycomb – Defective areas, such as honeycomb, must be chipped out of the solid concrete. Cut the edges as straight as possible at right angles to the surface or slightly undercut them to provide a key at the edge of the patch. If a shallow layer of mortar is placed on top of the honeycomb concrete, moisture will form in the voids and subsequent weathering will cause the mortar to span off. Fill shallow patches with mortar placed in layers not more than 1/2 inch thick. Give each layer a scratch finish to match the surrounding concrete by floating, rubbing, or tooling or on formed surfaces by pressing the form material against the patch while the mortar is still in place.

Large or deep patches can be filled with concrete held in place by forms. Reinforce and dowel these patches to the hardened concrete as shown in *Figure 6-80*. Patches usually appear darker than the surrounding concrete. Use some white cement in the mortar or concrete used for patching if appearance is important. A trial mix will help to determine the proportion of white and gray cements to use.

Before placing mortar or concrete in patches, keep the surrounding concrete wet for several hours. Then brush a grout of cement and water mixed to the consistency of paint into the surfaces to which the new material is to be bonded.

Start curing as soon as possible to avoid early drying. Damp burlap, tarpaulins, and membrane curing compounds are useful for this purpose.

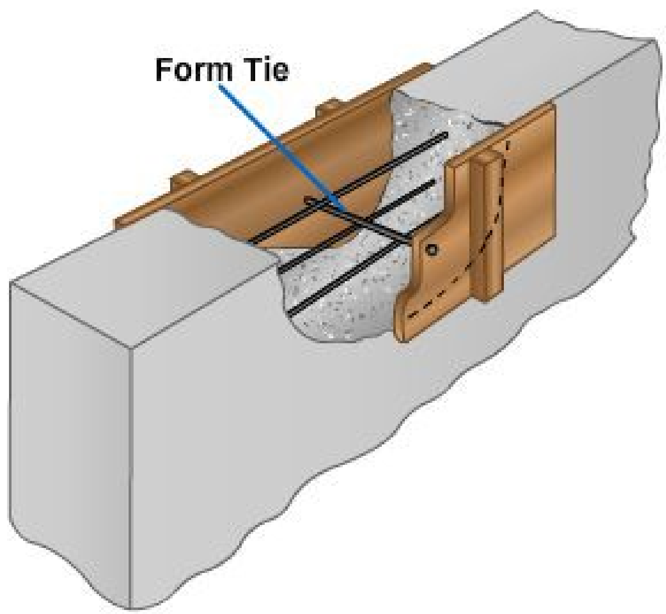


Figure 80 – Repair of large volumes of concrete.

Snap tie holes – Snap tie holes should be filled with small amounts of non shrink grout carefully packed into place. The grout should be mixed as dry as possible, with just enough water so it compacts tightly when forced into place. Tie rod holes extending through the concrete can be filled with grout with a pressure gun similar to an automatic grease gun.

Rock pockets – Rock pockets should be completely chipped out. The chipped out hole should have sharp edges and be so shaped that the grout patch will be keyed in place as shown in *Figure 6-81*. The surface of all holes that are to be patched should be kept moist for several hours before applying the grout. Grout should be placed in these holes in layers not over 1/4 inch thick and be well compacted. To reduce the amount of shrinkage and to make a better patch, allow the grout to set as long as possible before using it. Scratch each layer rough to improve the bond with the succeeding layer and smooth the last layer to match the adjacent surface.

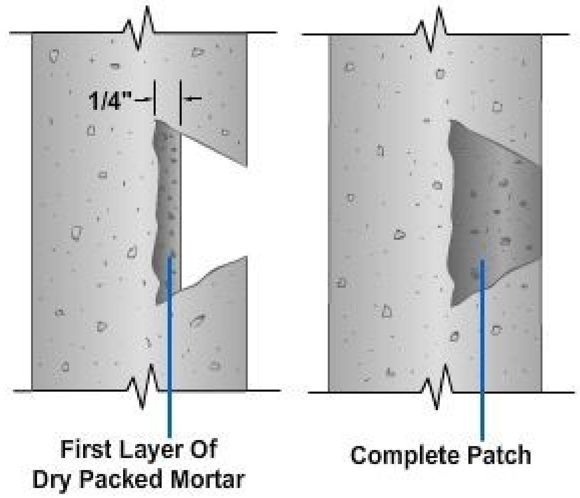


Figure 81 – Repairing concrete with dry packed mortar.

Where absorptive form lining has been used, the patch can be made to match the rest of the surface by pressing a piece of form lining against the fresh patch.

View A of Figure 6-76 shows an incorrectly installed patch. Feathered edges around a patch lack sufficient strength and will eventually break down. *View B* shows a correctly installed patch. The chipped area should be at least 1 inch deep with the edges at right angles to the surface. The correct method of screeding a patch is shown in V*iew C*. The new concrete should project slightly above the surface of the old concrete. It should be allowed to stiffen and then troweled and finished to match the adjoining surfaces.

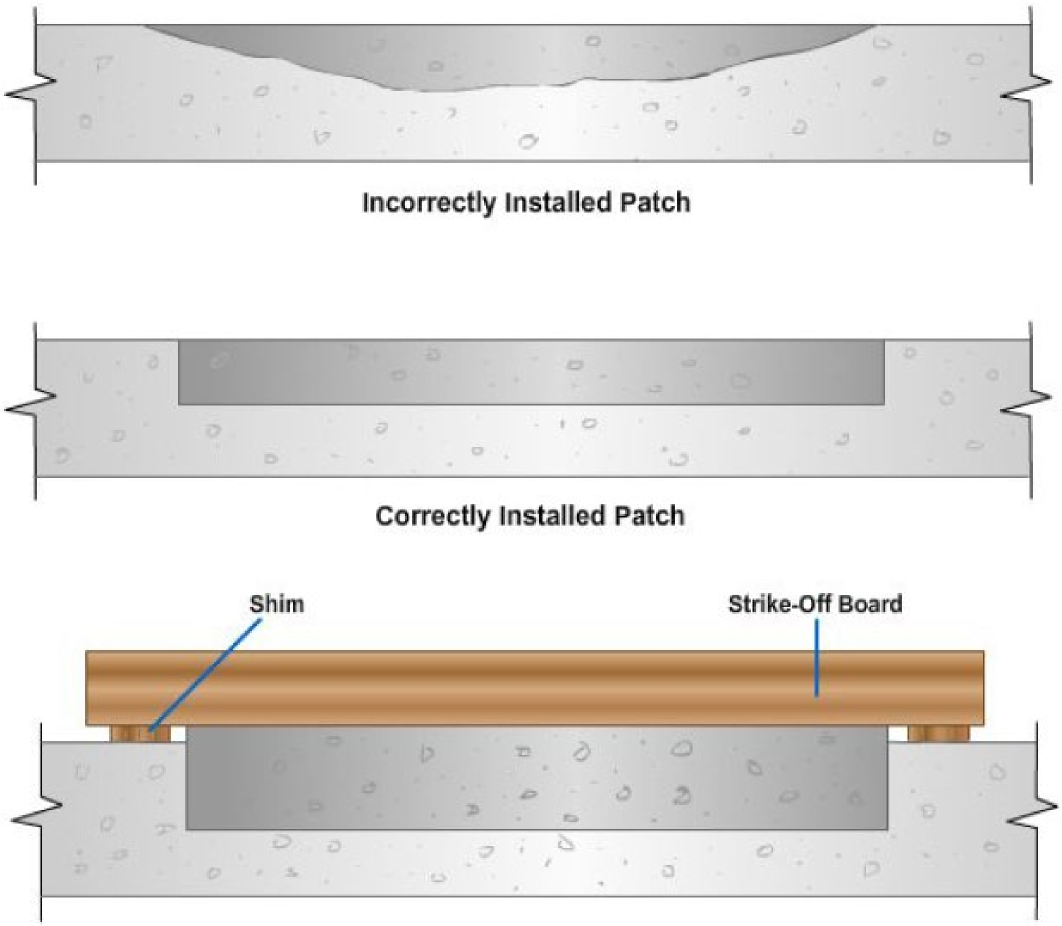


Figure-82 – Patching concrete.

12.0.0 PRECAST and TILT-UP CONCRETE

Concrete cast in the position it is to occupy in the finished structure is called cast-in- place concrete. Concrete cast and cured elsewhere is called precast concrete. Tilt-up concrete is a special type of precast concrete in which the units are tilted up and placed using cranes or other types of lifting devices.

Wall construction is frequently done with precast wall panels originally cast horizontally, sometimes one above the other, as slabs. This method has many advantages over the conventional method of casting in place in vertical wall forms. Since a slab form requires only edge forms and a single surface form, the amount of formwork and form materials required is greatly reduced. The labor involved in slab form concrete casting is much less than that involved in filling a high wall form. One side of a precast unit cast as a slab may be finished by hand to any desired quality of finishing.

The placement of reinforcing steel is much easier in slab forms, and it is easier to attain thorough filling and vibrating. Precasting of wall panels as slabs may be expedited by mass production methods not available when casting in place.

Relatively light panels for concrete walls are precast as slabs, as shown in *Figure 6-83*.

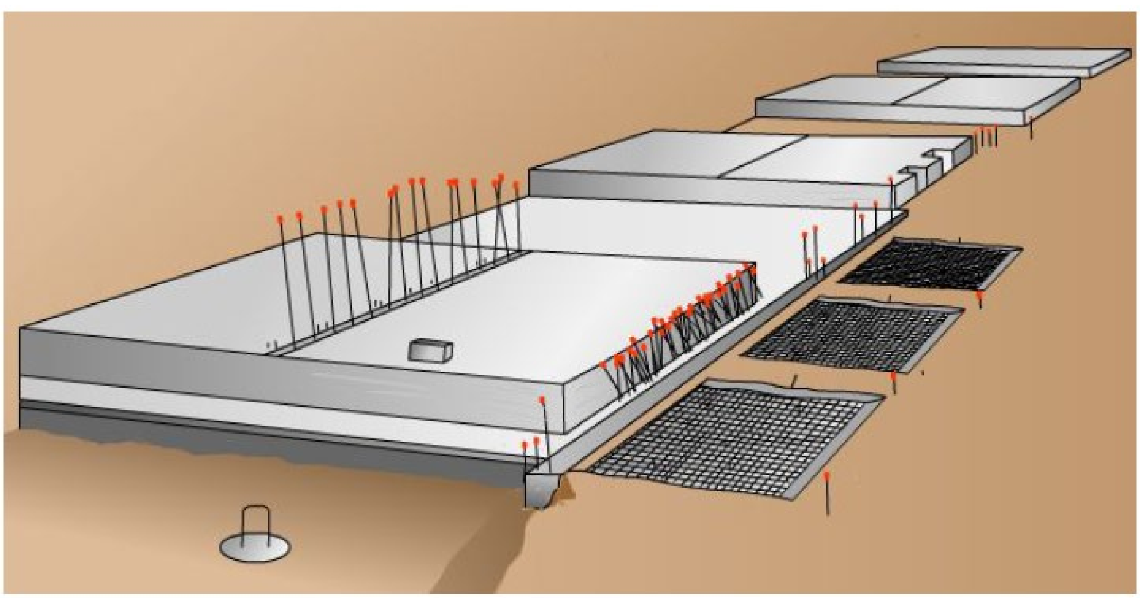


Figure 83 – Precast wall panels in stacks of three each.

The panels are set in place by cranes, using spreader bars as shown in *Figure 6-84*.

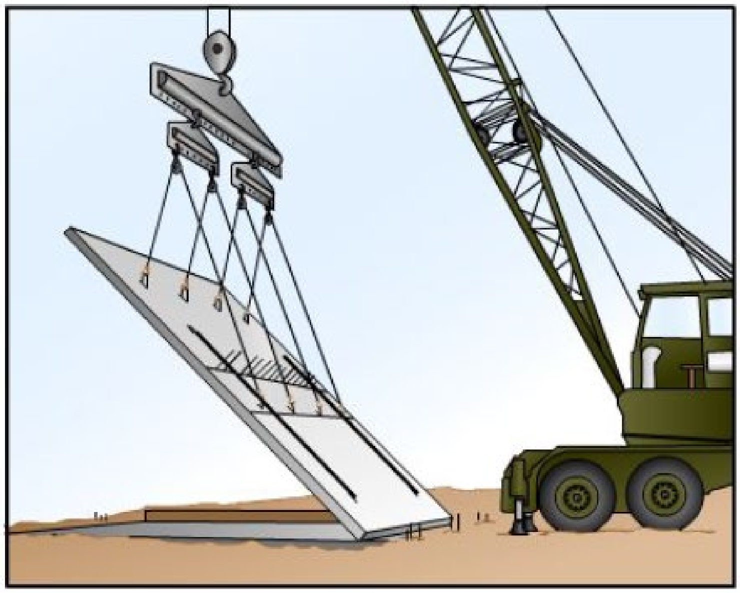


Figure 84 – Precast panels being erected by use of crane and spreader bars.

Figure 6-85 shows erected panels in final position.

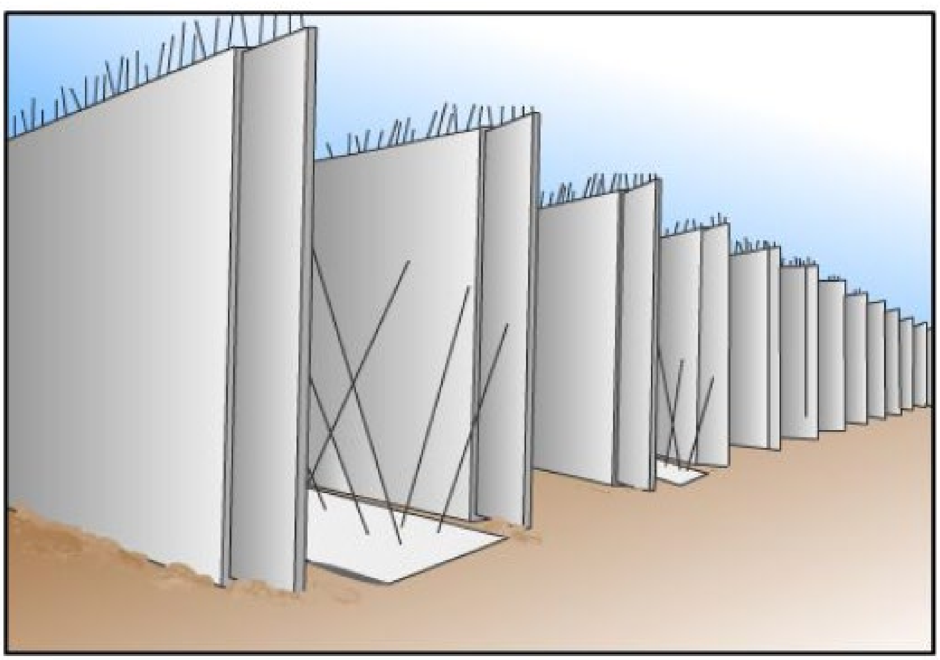


Figure 85 – Precast panels in position.

12.1.0 Casting

The casting surface is very important in making precast concrete panels. In this section, we will cover two common types: earth and concrete. Regardless of which method you use, you must cast the slab in a location that will permit easy removal and handling.

Castings can be made directly on the ground with cement poured into forms. These earth surfaces are economical but only last for a couple of concrete pours. Concrete surfaces, since they can be reused repeatedly, are more practical.

When building casting surfaces, keep the following points in mind:

- The subbase should be level and properly compacted.
- The slab should be at least 6 inches thick and made of 3,000 psi or higher reinforced concrete. Large aggregate, 2 ½ to 3 inches maximum, may be used in the casting slabs.
- If pipes or other utilities are to be extended up through the casting slab at a later date, they should be stopped below the surface and the openings temporarily closed. For wood, cork, or plastic plugs, fill almost to the surface with sand and top with a thin coat of mortar that is finished flush with the casting surface.
- It is important to remember that any imperfections in the surface of the casting slab will show up on the cast panels. When finishing the casting slab, you must ensure there is a flat, level, and smooth surface without humps, dips, cracks, or gouges. If possible, cure the casting surface keeping it covered with water. If you use a curing compound or surface hardener, make sure that it will not conflict with the later use of ***bond breaking agents***.

12.2.0 Forms

The material most commonly used for edge forms is 2 by lumber. The lumber must occasionally be replaced, but the steel or aluminum angles and charnels may be reused many times. The tops of the forms must be in the same plane so that they may be used for screeds. They must also be well braced to remain in good alignment.

Edge forms should have holes in them for rebar or for expansion/contraction dowels to protrude. These holes should be ¼ inch larger in diameter than the bars. At times, the forms are spliced at the line of these bars to make removal easier.

The forms, or rough bucks, for doors, windows, air conditioning ducts, and so forth are set before the steel is placed and should be on the same plane as the edge forms.

12.3.0 Bond Breaking Agents

Bond breaking agents are one of the most important items of precast concrete construction. The most important requirement is that they break the bond between the casting surface and the cast panel. Bond breaking agents must also be economical, fast drying, easily applied, easily removed, or leave a paintable surface on the cast panel, if desired. They are broken into two general types: sheet materials and liquids.

There are many bond breaking agents commercially available. Obtain the type best suited for the project and follow the manufacturer's application instructions. If commercial bond breaking agents are not available, several alternatives can be used.

- Paper and felt effectively prevent a bond with a casting surface, but usually stick to the cast panels and may cause asphalt stains on the concrete.
- Plywood, fiberboard, and metal effectively prevent a bond when oiled and can be used many times. Their initial cost is high and they leave joint marks on the cast panels.
- Canvas gives a very pleasing texture and is used where cast panels are lifted at an early stage. It should be either dusted with cement or sprinkled with water just before placing the concrete.
- Oil gives good results when properly used, but is expensive. The casting slab must be dry when the oil is applied, and the oil must be allowed to absorb before the concrete is placed. Do no use oil if the surface is to be painted, and never use crankcase oil.
- Waxes, such as spirit wax (paraffin) and ordinary floor wax, give good to excellent results. One mixture that may be used is 5 pounds of paraffin mixed with 1 ½ gallons of light oil or kerosene. The oil must

be heated to dissolve the paraffin.

- Liquid soap requires special care to ensure it is not used in excess amounts or the surface of the cast panel will be sandy.

Apply these materials after the side forms are in place and the casting slab is clean but **before** placing any reinforcing steel. To ensure proper adhesion of the concrete, keep all bond breaking materials off the reinforcing steel.

12.4.0 Reinforcements and Inserts

Reinforcing bars (rebar) should be assembled into mats and placed into the forms as a unit. This allows for rapid assembly on a jig and reduces walking on the casting surface, which has been treated with the bond breaking agent.

Use extra rebars at openings. Place them parallel to and about 2 inches from the sides of openings or diagonally across the corners of openings.

The bars may be suspended by conventional methods, such as with high chairs or from members laid across the edge forms. Do not use high chairs if the bottom of the cast panel is to be a finished surface. Another method is to first place half the thickness of concrete, place the rebar mat, and then complete the pour. Perform this method quickly to avoid a cold joint between the top and bottom layers.

When welded wire fabric (WWF) is used, dowels or bars must still be used between the panels and columns. WWF is usually placed in sheets covering the entire area and then clipped along the edges of the openings after erection.

If utilities are going to be flush mounted or hidden, pipe, conduit, boxes, sleeves, and so forth should be put into the forms at the same time as the reinforcing steel. If the utilities pass from one cast panel to another, the connections must be made after the panels are erected but before the columns are poured. If small openings are to go through the panel, a greased pipe sleeve is the easiest method of placing an opening in the form. For larger openings, such as air conditioning ducts, forms should be made in the same reamer as doors or windows.

After rebar and utilities have been placed, all other ***inserts*** should be placed. These will include lifting and bracing inserts, anchor bolts, welding plates, and so forth. You need to make sure these items are firmly secured so they won't move during concrete placement or finishing.

12.5.0 Pouring, Finishing, and Curing

With few exceptions, placing cast panels can be done in the same manner as other pours. Since the panels are poured in a horizontal position, you can use a stiffer mix. Use a minimum of six sacks of cement per cubic yard with a maximum of 6 gallons of water per sack of cement along with well graded aggregate. As pointed out earlier, you will have to reduce the amount of water used per sack of cement to allow for the free water in the sand. Large aggregate, up to 1 ½ inches in diameter, may be used effectively. Work the concrete into place by spading or vibration, and take extra care to prevent honeycomb around the outer edges of the panel.

Normal finishing methods should be used, but many finishing styles are available for horizontally cast panels. Some finishing methods include patterned, colored, exposed aggregate, broomed, floated, or steel troweled. Regardless of the finish used, finishers must be cautioned to do the finishing of all panels in a uniform manner. Spots, defects, uneven brooming, or troweling, and so forth will be highly visible when the panels are erected.

Without marring the surface, curing should be started as soon as possible after finishing. Proper curing is important, so cure cast panels just like any other concrete to achieve proper strength. Curing compound, if used, prevents bonding with other concrete or paint.

12.6.0Lifting Equipment and Attachments

Tilt-up panels can be set up in many different ways and with various kinds of power equipment. The choice depends upon the size of the job. Besides the equipment, a number of attachments are used.

12.6.1 Equipment

The most popular power equipment is a crane. But other equipment used includes a winch and an A frame, used either on the ground or mounted on a truck. When a considerable number of panels are ready for tilting at one time, power equipment speeds up the job.

12.6.2 Attachments

Many types of lifting attachments are used to lift tilt-up panels. Some of these are locally made and are called hairpins; other types are available commercially. Hairpin types are made on the job site from rebar by making 180° bends in the ends of two vertical reinforcing bars. The hairpins are then placed in the end of the panel before the concrete is poured. These lifting attachments must protrude from the top of the form for attaching the lifting chains or cables, but go deep enough into the panel form so they won't pull out.

Among the commercial types of lifting attachments, you will find many styles with greater lifting capacities that are more dependable than hairpins if properly installed. These are used with lifting plates. For proper placement of lifting inserts, refer to the plans or specs.

12.6.3 Spreader Bars

Spreader bars, shown in *Figure 6-80*, may be permanent or adjustable, but must be designed and made according to the heaviest load they will carry plus a safety factor. They are used to distribute the lifting stresses evenly, reduce the lateral force applied by slings, and reduce the tendency of panels to bow.

12.7.0 Point Pickup Methods

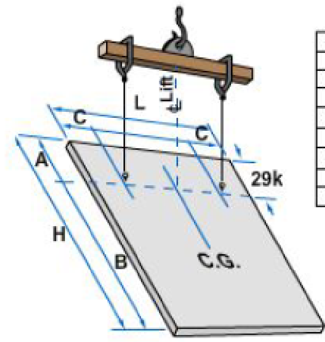
Once the concrete has reached the desired strength, the panels are ready to be lifted. The strength of the inserts is governed by the strength of the concrete.

⚠ CAUTION ⚠

An early lift may result in cracking the panel, pulling out the insert, or total concrete failure. Taking the time to wait until the concrete has reached its full strength prevents problems and minimizes the risk of injury.

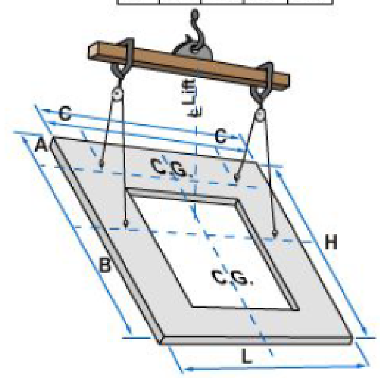
There are several pickup methods. The following are just some of the basics. Before using these methods on a job, make sure that you check plans and specs to see if these are stated there. *Figure 6-86* shows four different pickup methods: 2, 2-2, 4-4, and 2-2-2.

Two Point Pickup Is Best Suited To Wall Panels 10' To 18' In Height, And Up To 18' In Width For Panels 5" To 8" In Panel Tickness.

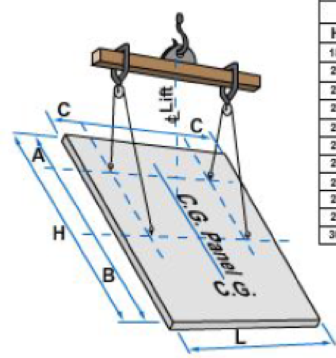


Trial Points			
H	A	L	C
8'	2' 3"	14'	2' 10"
10'	2' 10"	15'	3' 1"
12'	3' 6"	16'	3' 4"
14'	4' 1"	17'	3' 6"
16'	4' 7"	18'	3' 8"
18'	5' 0"	19'	3' 10"
20'	5' 2"	20'	4' 1"

Truck Door 2 - 2 Pickup Trial Locations				
H	A	B	L	C
18'	3' 0"	7' 10"	14'	2' 10"
20'	3' 3"	8' 6"	16'	3' 4"
22'	3' 7"	9' 6"	18'	3' 8"
24'	3' 10"	10' 6"	19'	3' 10"
26'	4' 0"	11' 6"	20'	4' 1"
27'	4' 3"	12' 0"	21'	4' 4"
28'	4' 6"	12' 6"	22'	4' 6"
29'	4' 9"	12' 10"	23'	4' 8"
30'	5' 0"	13' 1"	24'	4' 11"

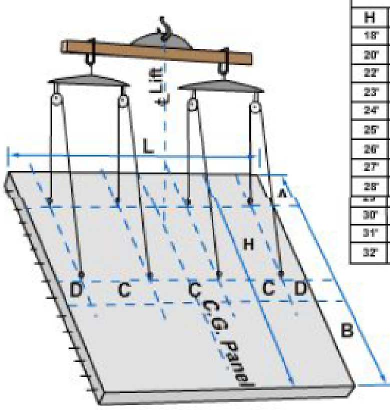


2 - 2 Point Pickup Trial Locations				
H	A	B	L	C
18'	3' 3"	7' 7"	12'	2' 6"
20'	3' 7"	8' 4"	14'	2' 10"
22'	3' 11"	9' 3"	15'	3' 1"
23'	4' 2"	9' 7"	16'	3' 4"
24'	4' 4"	10' 1"	17'	3' 6"
25'	4' 6"	10' 6"	18'	3' 8"
26'	4' 8"	11' 0"	19'	3' 10"
27'	4' 10"	11' 4"	20'	4' 1"
28'	5' 0"	11' 9"	21'	4' 4"
29'	5' 2"	12' 2"	22'	4' 6"
30'	5' 4"	12' 7"	23'	4' 8"



2 - 2 - 2 Point Pickup Trial Locations				
H	A	B	L	C
30'	4' 2.5"	9' 7"	16'	3' 4"
32'	4' 6"	10' 3"	18'	3' 8"
34'	4' 10"	10' 10"	19'	3' 10"
36'	5' 0"	11' 6"	20'	4' 1"
38'	5' 4"	12' 2"	22'	4' 6"
40'	5' 7"	12' 3"	24'	4' 11"
42'	5' 9"	12' 4"	26'	5' 1"

4 - 4 Point Pickup Trial Locations					
H	A	B	L	C	D
18'	3' 3"	7' 7"	18'	4' 8"	2' 0"
20'	3' 7"	8' 4"	20'	5' 3"	2' 1.5"
22'	3' 11"	5' 3"	22'	5' 10"	2' 3"
23'	4' 2"	9' 7"	24'	6' 4"	2' 6"
24'	4' 4"	10' 1"	26'	6' 10"	2' 9"
25'	4' 6"	10' 6"	28'	7' 4"	3' 0"
26'	4' 8"	11' 0"	30'	8' 0"	3' 0"
27'	4' 10"	11' 4"	32'	8' 6"	3' 4"
28'	5' 0"	11' 9"	34'	9' 0"	3' 6"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30'	5' 4"	12' 7"	38'	10' 2"	3' 10"
31'	5' 7"	13' 0"	39'	10' 4"	4' 0"
32'	5' 9"	13' 4"	40'	10' 6"	4' 3"



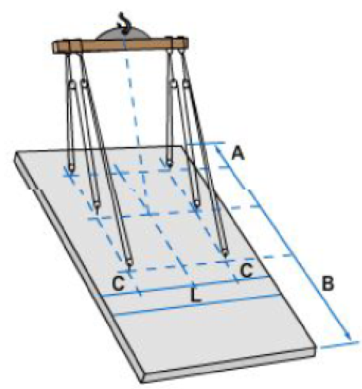


Figure 80 – Different types of pickup points.

The 2-point pickup is the simplest method, particularly for smaller panels. Fasten the pickup cables or chains directly from the crane hook or spreader bar to two pickup points on or near the top the precast panel.

The 2-2 point pickup is a better method and is more commonly used. Variations of the 2-2 are the 4-4 and 2-2-2, or combinations of pickup points as designated in the job site specifications. These methods use a combination of spreader bars, sheaves, and equal length cables. The main purpose is to distribute the lifting stress throughout the panel during erection. Remember, the cables must be long enough to allow ample clearance between the top of the panel and the sheaves or spreader bar.

12.8.0 Erecting, Bracing, and Jointing Panels

Erecting is an important step in the construction phase of the project. Before you start the erecting phase, and for increased safety, make sure all your tools, equipment, and braces are in proper working order. All personnel must be well informed and the signalman and crane operator understand and agree on the signals to be used. During the erection of the panels, make sure that the signalman and line handler are not under the panel and that all unnecessary personnel and equipment are away from the lifting area. After the erection is done, make sure that all panels are properly braced and secured before unhooking the lifting cables.

Bracing is an especially important step. After all the work of casting and placing the panels, you want them to stay in place. The following are some steps to take before lifting the panels:

- Install the brace inserts into the panels during casting if possible.
- Install the brace inserts into the floor slab either during pouring or the day before erection.
- Install solid brace anchors before the day of erection.
- If brace anchors must be set during erection, use a method that is fast and accurate.

Although there are several types of bracing, pipe or tubular braces are the most common. They usually have a turnbuckle welded between sections for adjustment. Some braces are also made with telescoping sleeves for greater adaptability. *Figure 6- 80* shows tube type braces used to hold up panels. Cable braces are normally used for temporary bracing and for very tall panels. Their flexibility and tendency to stretch make them unsuitable for most projects. Wood bracing is seldom used except for low, small panels or for temporary bracing.

Jointing the panels is simple. Just tie all the panels together, covering the gap between them. You can weld, bolt. Or pour concrete columns or beams. Steps used to tie the panels should be stated in the plans and specs.

Summary

Concrete is a very important construction material, since it is comparatively economical and easy to make, offering continuity, solidity, and the ability to bond with other materials. The keys to good quality concrete are the raw materials required to make concrete and the mix design as specified in the project specifications, which includes methods and mixing times. Tilt-up construction involves several considerations, including what projects it might be suitable for and lifting methods needed to put these pieces in place.

Trade Terms Introduced in this Chapter

Accelerators	Additives which, when added to paint, concrete, mortar, or grout mix, speed the rate of hydration and thereby cause it to set or harden sooner.
Admixture	An ingredient other than cement, aggregate, or water that is added to a concrete or mortar mixture to affect the physical or chemical characteristics of the concrete or mortar. The most common admixtures affect plasticity, air entrainment, and curing time.
Aggregate	Crushed rock or gravel screened to size for use in road surfaces, concrete, or bituminous mixes
Air-entrained concrete	Concrete containing millions of trapped air bubbles.
Air-entraining agent	An admixture for concrete or mortar mixes that causes minute air bubbles to form within the mix. Air entrainment is desirable for workability of the mix and prevention of cracking in the freeze/thaw cycle.
Batch	The amount of concrete mixed at one time regardless of quantity.
Bond	The adhesion of cement paste to aggregate.
Bond breaking agents	Materials used to prevent adhesion between freshly placed concrete and the substrate.
Bracing	A temporary support for aligning vertical concrete work.
Broomed	Concrete that has been brushed with a broom when fresh in order to improve its traction or to create a distinctive texture.
Cement	Fuzed and pulverized limestone and clay.
Charging	The insertion of a predetermined mixture or quantity of materials into a concrete mixer.
Cleats	Small blocks of wood nailed to the surface of a wood member to stop or support another member.

Compacting	Eliminating voids in concrete by vibration, tamping, rolling, or some other method or combination of methods.
Compressive strength	The resistance capacity of any material, but especially structural members, to crushing force. Compressive strength is usually expressed as the maximum number of pounds per square inch that can be resisted without failure.
Consolidation	Compaction of freshly poured concrete by tamping, rodding, or vibrating to eliminate voids and to ensure total envelopment of aggregate and reinforcement.
Construction joints	Joints that run through concrete. Made by pouring sections of a structure at different times.
Control joints	A formed, sawed, or tooled groove in a concrete structure. The purpose of the joint is to create a weakened plane and to regulate the location of cracking resulting from the dimensional change of different parts of the structure. Also known as a contraction joint.
Curing	Maintaining the proper moisture and temperature after placing or finishing concrete to assure proper hydration and hardening.
Edging	The process of rounding to reduce the possibility of chipping or spalling exposed edges of concrete slabs.
Finish	The texture of a surface after compacting and finishing operations have been performed. (Examples are exposed aggregate, rubbed, and sack-rubbed.)
Finishing	Leveling, smoothing, compacting, and otherwise treating surfaces of fresh or recently placed concrete or mortar to produce the desired appearance and service.
Floating	The operation of finishing a fresh concrete or mortar surface by use of a float, preceding

	troweling when that is the final finish.
Forms	Temporary structures or molds for the support of concrete while it is setting and gaining sufficient strength to be self- supporting.
Formwork	The total system of support for freshly placed concrete,including the mold or sheathing which contacts the concrete, as well as all supporting members, hardware, and necessary bracing
Grout	A mixture of sand, cement, and water that can be poured.
Honeycombing	Sections of weak, porous concrete.
Hydrostatic head	The pressure in a fluid, expressed as the height of a column of fluid that will provide an equal pressure at the base of the column.
Insert	A unit of hardware embedded in concrete or masonry to provide a means for attaching something.
Isolation joints	Joints positioned so as to separate concrete from adjacentsurfaces or into individual structural elements which are not in direct physical contact, such as an expansion joint.
Laitance	A milky deposit on the surface of new cement or concrete, usually caused by too much water.
Mixing time	The elapsed time for mixing a batch of concrete or mortar.
Particle size distributions	Tabulations of the result of mechanical analysis expressed as the percentage by weight passing through each of a series of sieves.
Placing Rate	The rate at which concrete is placed, generally expressed as feet per hour.
Pouring	The process of placing and consolidating concrete.
Precast concrete	Concrete structural components, such as piles, wall panels, beams, etc., fabricated at a location other than in-place.

Ready mixed concrete	Concrete manufactured for delivery to a purchaser in a plastic and unhardened state.
Rebar	A steel bar, usually with manufactured deformations, used in concrete and masonry construction to provide additional strength. Also known as reinforcing bar.
Reinforcement	Bars, wires, strands, and other slender members embedded in concrete such a manner that the reinforcement and the concrete act together in resisting forces.
Retarders	Admixtures which delay the setting of cement paste, andhence of mixtures such as mortar- or concrete-containing cement.
Rodding	Compaction of concrete by means of a tamping rod.
Screeding	The operation of forming a surface by striking off concrete lying above the desired plane or shape.
Segregation	The differential concentration of the components of mixed concrete, aggregate, or the like, resulting in nonuniform proportions in the mass.
Shrinkage	Concrete contraction due to curing and excess water in the mix.
Slump	A measure of consistency of freshly mixed concrete, mortar, or stucco equal to the subsidence measured to the nearest 1/4” (6 mm) of the molded specimen immediately after removal of the slump cone.
Slump test	A means of sample testing concrete for consistency; a measure of the plasticity of a concrete mix.
Stripping	The removal of mold forms from hardened concrete.
Tamping	The operation of compacting freshly poured concrete byrepeated blows or penetrations with a

	tamping device.
Ties	Metal strips used to tie concrete forms together. (Types are cross, double-strand single, figure-eight, saddle, simple, snap, wall tie)
Tilt-up concrete	A method of concrete construction in which members are cast horizontally at a location adjacent to their eventual position and tilted into place after removal of forms.
Troweling	Smoothing and compacting the unformed surface of fresh concrete by strokes of a trowel.
Vibration	Energetic agitation of freshly mixed concrete during placement by mechanical devices, either pneumatic or electric, that create vibratory impulses of moderately high frequency that assist in evenly distributing and consolidating the concrete in the formwork.
Welded-wire fabric	A series of longitudinal and transverse wires of various gauges, arranged at right angles to each other and welded at all points of intersection; used for concrete slab reinforcement. Also known as welded-wire mesh.
Workability	The property of freshly mixed concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed, compacted, and finished.